

EVALUATION OF EDUCATIONAL-SOFTWARE AND PAPER-
BASED RESOURCES FOR TEACHING LOGICAL-THINKING
SKILLS TO GRADE SIX AND SEVEN STUDENTS

PETER JOHN FENRICH

A thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy (Education)

Faculty of Education and Languages
Open University Malaysia

2015

DECLARATION

Name: Peter John Fenrich

Matric Number:

I hereby declare that this dissertation is the result of my own work, except for quotations and summaries, which have been duly acknowledged.

Signature: 

Date: August 27, 2015

EVALUATION OF EDUCATIONAL-SOFTWARE AND PAPER-BASED RESOURCES FOR TEACHING LOGICAL-THINKING SKILLS TO GRADE SIX AND SEVEN STUDENTS

PETER JOHN FENRICH

August 2015

ABSTRACT

Guided by the objectives of investigating whether there were any differences between the effectiveness of the paper-based materials and educational software in teaching logical-thinking skills and transferring those skills to new problems and determining the efficacy of the paper-based materials and educational software in teaching logical-thinking skills and transferring those skills to new problems, a mixed-method research approach was used. A qualitative assessment was conducted to ascertain the appropriateness of the materials and a quantitative assessment was done using a pre-test, post-test, experimental design to assess the effectiveness of the materials in teaching logical-thinking skills. Based on the qualitative analysis, after the initial materials were modified through the information gained from the pilot students and changes were put in as suggested by the reviewers through their iterative reviews of the materials, it was determined that the reviewers considered that the events of instruction addressed in this intervention (gaining attention, informing the learner of the learning outcome, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer) provided the attributes needed to effectively teach the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning. For the quantitative analysis, one-way ANOVAs were performed to compare an experimental group learning from educational software (32 students), an experimental group learning from paper-based materials (32 students), and a control group (32 students). Given significance was found between the groups, Tukey HSD Post Hoc Tests were done. For each test, the subjects taught through educational software and those taught through paper-based materials scored significantly higher in logical-thinking ability than the control group, except for the subskills of patterning and deductive reasoning for the subjects learning through educational software, and the skill of deductive reasoning for the subjects learning through paper-based materials. For the transfer learning scores, the subjects learning through paper-based materials scored significantly higher than the control group. There were no significant differences between subjects taught through paper-based materials and those taught through educational software on any test. Based on paired samples t-test results, the subjects learning from educational software and those learning from paper-based materials had significant percentage gains on all of their pre-test to post-test scores, except the subjects learning through paper-based materials showed no significant gains on the sequencing and deductive-reasoning skills.

Keywords:

Logical thinking, Instructional design, Qualitative analysis, Quantitative analysis

PENILAIAN PERISIAN PENDIDIKAN DAN SUMBER-SUMBER BERASASKAN
KERTAS UNTUK PENGAJARAN KEMAHIRAN PEMIKIRAN LOGIKAL
KEPADA PELAJAR GRED ENAM DAN TUJUH

PETER JOHN FENRICH

August 2015

ABSTRAK

Satu pendekatan penyelidikan bercampur telah digunakan untuk menyiasat sama ada terdapat apa-apa perbezaan antara keberkesanan bahan-bahan berasaskan kertas dengan perisian pendidikan dalam pengajaran kemahiran pemikiran logikal. Penyiasatan juga melihat samada kemahiran tersebut boleh diindahkan kepada masalah baharu. Satu pentaksiran kualitatif telah dijalankan untuk menentukan kesesuaian bahan-bahan dan pentaksiran kuantitatif telah dilakukan dengan menggunakan ujian pra, ujian pasca dan reka bentuk eksperimen untuk menilai keberkesanan bahan-bahan dalam pengajaran kemahiran logikal. Berdasarkan analisis kualitatif, selepas bahan awal diubah suai melalui maklum balas yang diperoleh daripada pelajar perintis, perubahan telah dibuat berdasarkan cadangan daripada penyemak melalui maklum balas iteratif bahan-bahan oleh mereka, telah dikenal pasti bahawa penyemak menganggap bahawa peristiwa-peristiwa pengajaran dalam intervensi ini (mendapatkan perhatian, memaklumkan kepada pelajar tentang hasil pembelajaran, menyampaikan bahan, menyediakan bimbingan pembelajaran, mendapatkan maklum balas prestasi, memberikan maklum balas, mentaksir prestasi, dan meningkatkan pengekalan dan pemindahan) membekalkan atribut-atribut yang diperlukan untuk mengajar secara berkesan kemahiran pemikiran logikal klasifikasi, penaakulan analogi, penjujukan, pencorakan, dan penaakulan deduktif. Untuk analisis kuantitatif, ANOVA sehalu telah dijalankan untuk membanding kumpulan eksperimen yang belajar daripada perisian pendidikan (32 pelajar), dengan kumpulan eksperimen yang belajar daripada bahan-bahan berasaskan kertas (32 pelajar) dan kumpulan kawalan (32 pelajar). Ujian *Tukey HSD Post Hoc* telah dilakukan untuk mengesan perbezaan antara kumpulan tersebut. Bagi setiap ujian, pelajar yang diajar dengan menggunakan perisian pendidikan dan pelajar yang diajar dengan menggunakan bahan-bahan berasaskan kertas memperoleh skor signifikan yang lebih tinggi dalam keupayaan pemikiran logikal berbanding kumpulan kawalan, kecuali bagi subkemahiran pencorakan dan penaakulan deduktif bagi pelajar yang belajar melalui perisian pendidikan, dan kemahiran penaakulan deduktif bagi pelajar yang belajar melalui bahan-bahan berasaskan kertas. Bagi skor pemindahan pembelajaran, pelajar yang belajar melalui bahan-bahan berasaskan kertas memperoleh skor signifikan yang jauh lebih tinggi daripada kumpulan kawalan. Tiada perbezaan yang signifikan antara pelajar yang diajar melalui bahan-bahan berasaskan kertas dan pelajar yang diajar melalui perisian pendidikan di mana-mana ujian. Berdasarkan sampel berpasangan keputusan ujian-t, pelajar yang belajar daripada perisian pendidikan dan pelajar yang belajar melalui bahan-bahan berasaskan kertas mempunyai peratusan peningkatan yang ketara dalam semua skor ujian pasca berbanding ujian pra, kecuali pelajar yang belajar melalui bahan-bahan berasaskan kertas tidak menunjukkan peningkatan signifikan dalam penjujukan dan kemahiran penaakulan deduktif.

Kata kunci:

Pemikiran logik, reka bentuk pengajaran, analisis kualitatif, analisis kuantitatif

DEDICATION

This dissertation is particularly dedicated to Jayne, my wife, who supported my efforts, was understanding about the time I needed to complete my dissertation, and helped me persevere. To my three children, Shannon, Alexander, and David, thank you for your support in this endeavour, being patient while I worked on my computer for endless hours, and making me laugh as laughter gives spirit. To all four of you, my apologies for the times when I must have been tired and grumpy. Mom, thank you for all the years of unconditional love, support, and encouragement. Dad, you always valued education. I imagine you never dreamed that your values would lead to this achievement.

ACKNOWLEDGEMENTS

There are many who helped make this dissertation a reality. I am so grateful for your support, encouragement, and help. Dr. Kaur, thank you so much for your feedback. Your insights were invaluable. I also appreciate your encouragement. It greatly helped when I was feeling overwhelmed. Barbara, you inspired me to pursue this research. What you achieved as a teacher in developing so many students' thinking skills is remarkable. I hope that I have captured some of your brilliance in the instructional interventions of this research. I would also like to thank the British Columbia Institute of Technology for the release time given to help me complete my coursework and research. I thank all of you who reviewed the materials. Your time, dedication, and perceptions made a huge difference.

TABLE OF CONTENTS

TITLE PAGE	
DECLARATION	ii
ABSTRACT	iii
DEDICATION	v
ACKNOWLEDGEMENTS	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	x
Chapter 1 Introduction	1
1.0 Background of the Study	1
1.1 Problem Statement	6
1.2 Objectives of the Study	13
1.3 Research Questions	13
1.3.1 Dependent and Independent Variables	14
1.4 Significance of the Study	14
1.5 Limitations of the Study	17
1.6 Definitions	19
1.6.1 Definitions	19
1.6.2 Acronyms	20
1.7 Assumptions	20
1.8 Summary	22
Chapter 2 Literature Review	23
2.0 Introduction	23
2.1 Thinking Skills	24
2.1.1 Higher-order and Lower-order Thinking Skills	25
2.1.2 Logical-thinking Skills	29
2.1.3 Critical-thinking Skills	33
2.1.4 Creative Thinking Skills	34
2.1.5 Divergent-thinking Skills	35
2.1.6 Convergent-thinking Skills	37
2.1.7 Metacognition Skills	38
2.2 Learning Theories	39
2.2.1 Cognitive Development and Related Research	39
2.2.2 Long-term and Short-term Memory	46
2.2.3 Constructivism	49
2.2.4 Practice and Feedback	50
2.2.5 Metacognition	51
2.2.6 Motivation	51
2.3 Instructional Design	52
2.3.1 Instructional Development Cycle Models	53
2.3.2 Gagné’s Nine Events of Instruction	62
2.3.3 Designing Learning for Higher-order Thinking	66
2.3.4 Instructional Strategies for Teaching Analogies	74
2.4 Transfer of Learning	74
2.5 Screen and Interface Design	76
2.6 Assessment of Thinking Skills	77

2.7	Findings on Teaching Higher-Order Thinking Skills	83
2.7.1	Educational Software	84
2.7.2	Paper-based Materials	111
2.8	Findings for Comparable Interventions	113
2.8.1	Expected Results for Comparable Interventions	114
2.8.2	Educational Software Compared to Paper-based Interventions	115
2.9	Research on the Transfer of Thinking Skills	117
2.9.1	Transfer of Skills through Educational Software	117
2.9.2	Transfer of Skills through Paper-based Materials	120
2.10	Literature Review Findings Summary	122
2.11	Theoretical Framework	125
2.11.1	Combined Instructional Design and Development Model	125
2.11.2	Creating Effective Instructional Materials	130
2.12	Summary	132
Chapter 3 Methodology		135
3.0	Introduction	135
3.1	Research Design	135
3.1.1	Qualitative Method	136
3.1.2	Qualitative Analysis in the Instructional Development Cycle	137
3.1.3	Qualitative Analysis in Gagné's Nine Events of Instruction	151
3.1.4	Trustworthiness of the Qualitative Analysis	165
3.1.5	Quantitative Methods	173
3.1.6	Internal Validity	175
3.1.7	External Validity	182
3.1.8	The Treatment	183
3.2	Population and Sample	185
3.2.1	Reviewers Participating in the Qualitative Assessment	186
3.2.2	Students Participating in the Qualitative Assessment	187
3.2.3	Students Participating in the Quantitative Assessment	187
3.3	Instrumentation	189
3.3.1	Qualitative Research Instruments	189
3.3.2	Quantitative Research Instruments	191
3.4	Data Collection Procedures	193
3.4.1	Qualitative Data Collection Procedures	193
3.4.2	Quantitative Data Collection Procedures	193
3.5	Data Analysis Procedures	194
3.5.1	Qualitative Analysis Procedures	194
3.5.2	Quantitative Analysis Procedures	195
3.6	Approvals	196
3.7	Summary	197
Chapter 4 Findings		198
4.0	Introduction	198
4.1	Research Question 1	199
4.1.1	The Context	199
4.1.2	The Attributes	199
4.2	Research Questions 2, 3, and 4	205
4.2.1	Combined Direct and Transfer Learning	206
4.2.2	Direct Learning	209
4.2.3	ESG Amount of Learning	212
4.2.4	PBG Amount of Learning	213

4.2.5	CG Amount of Learning	215
4.3	Research Questions 5, 6, and 7	216
4.3.1	Total Transfer Learning	216
4.4	Test Reliability	218
4.4.1	Comments Regarding the Internal Consistency	219
4.5	Summary	220
Chapter 5	Discussion and Conclusions	225
5.0	Introduction	225
5.1	Summary of the Main Findings	225
5.1.1	Main Findings for Research Question 1	225
5.1.2	Main Findings for Research Questions 2, 3, and 4	226
5.1.3	Main Findings for Research Questions 5, 6, and 7	229
5.2	Discussion of the Findings	230
5.2.1	Discussion Regarding Research Question 1	231
5.2.2	Discussion Regarding Research Question 2	234
5.2.3	Discussion Regarding Research Question 3	235
5.2.4	Discussion Regarding Research Question 4	237
5.2.5	Discussion Regarding Gains in Amount Learned	238
5.2.6	Discussion Regarding Research Question 5	242
5.2.7	Discussion Regarding Research Question 6	243
5.2.8	Discussion Regarding Research Question 7	244
5.2.9	Discussion Regarding Gains in Amount Learned	244
5.3	Qualitative Versus Quantitative Findings	245
5.4	Implications	246
5.5	Limitations	248
5.6	Suggestions for Further Research	249
5.7	Conclusion	251
	REFERENCES	253
	APPENDIX A – APPROVAL LETTERS	268
	APPENDIX B – PRE-TESTS AND POST-TESTS	273
	APPENDIX C – SAMPLE LESSON MATERIAL	349

List of Tables

Table 1.1	Summary of the Research Gap	11
Table 3.1	Differences Between the Paper-based and Educational-software Interventions	146
Table 3.2	Gender of Sample	188
Table 3.3	Grade and Age of Sample	188
Table 4.1	Pre-test and Post-test (df=2,93) Combined Direct and Transfer Learning Scores	206
Table 4.2	Deductive-reasoning Skill Combined Direct and Transfer Learning Scores T-test Results	208
Table 4.3	Pre-test and Post-test (df=2,93) Direct Learning Scores	209
Table 4.4	Deductive-reasoning Skill Direct Learning Scores T-test Results	211
Table 4.5	ESG Amount of Learning	212
Table 4.6	PBG Amount of Learning	213
Table 4.7	CG Amount of Learning	215
Table 4.8	Total Transfer Learning Scores	216
Table 4.9	Total Amount of Transfer Learning	217
Table 4.10	Test Reliability	218

List of Figures

Figure 2.1	Bloom's Taxonomy	26
Figure 2.2	Revised Bloom's Taxonomy	27
Figure 2.3	ADDIE Model	54
Figure 2.4	Nonlinear Instructional Development Cycle Model	126
Figure 2.5	Systematic Instructional Design Process	127
Figure 2.6	Gagné's Nine Events of Instruction	128
Figure 2.7	Combined Instructional Design and Development Model	129
Figure 3.1	Initial goal analysis of this study	138
Figure 3.2	Sample menu from the paper-based intervention	145
Figure 3.3	Sample menu from the educational-software intervention	145
Figure 3.4	Sample page design from the paper-based intervention	145
Figure 3.5	Sample page design from the educational-software intervention	146
Figure 3.6	Final goal analysis of this study	155

Chapter 1

Introduction

The introduction presents the background of the study, problem statement, objectives of the study, research questions, significance of the study, limitations of the study, definitions, and assumptions.

1.0 Background of the Study

This research study was conceived based on an extensive literature review. The literature review strongly supported that parents, teachers, administrators, researchers, and employers from around the world all seem to be in general agreement that students who left the school system did not have the higher-order thinking skills that were needed in both the workplace and life (Burkhart, 2006; Lee, 2008). As well, the need for higher-order thinking skills in the workplace was increasing due to the challenges of growing global competition (Almatrodi, 2007), greater complexities in the world (Gruberman, 2005), and rapidly-changing economies (Lee, 2010). As stated by McDonald (2003),

The central purpose of every school activity should lead students to develop their thinking abilities. Educators need to help children, who represent the future leaders and decision makers of our societies, develop the ability to think logically and use reason in life situations (p. 1).

The ability to transfer higher-order thinking skills to other domains is also important. Higher-order thinking skills enable individuals to generically solve a wide variety of problems as opposed to only knowing how to solve a limited number of specific types of problems (Walker, 2001; Young & Maxwell, 2007). In other words, it

is important for thinking skills to transfer beyond the context in which they are taught (Abrami, 2008; Reid, 2010; Solomon, 2008). However, it cannot be safely assumed that the skills will transfer to new situations (Enniss, 2006; Jeremiah, 2012; Reid, 2010; Wilber, 2000), as research has shown mixed results (Wilber, 2000) and studies have shown that even some of the better students have difficulties transferring higher-order thinking skills to new situations (Mains, 1997).

Apart from issues related to transferring higher-order thinking skills, there are also difficulties in teaching higher-order thinking skills. It is not a simple matter to teach higher-order thinking skills since many traditional methods of teaching do not inherently address those skills (Hugo, 1989; Lee, 2010). Some teachers do not have the skills needed to teach specific higher-order thinking skills (Jeremiah, 2012; Petris, 2009; Reid, 2010; Rigmaiden, 2011), while other teachers only have minimal skills in teaching higher-order thinking skills (Almatrodi, 2007; Burkhart, 2006). Professional development for teachers with respect to teaching higher-order thinking skills can be haphazard (Lane, 2003) or non-existent; leaving many teachers to rely on intuition rather than a guided plan for creating strategies for teaching higher-order thinking skills (Miller, 2003). A further problem is that many teachers continue to use the lecture method as their primary way to teach (Roop, 2002).

Flaws in teaching tactics have also contributed to the less than desired development of higher-order thinking skills. For example, some teachers who have asked higher-order thinking questions made one of two mistakes related to the wait time after the question was asked. Firstly, if a student quickly came up with an answer, teachers let that student immediately answer the question for the whole class. Consequently, the weaker students' learning was compromised because they did not have the time to think deeply enough to come up with their own answer. Secondly,

some teachers, who did not receive a quick response, provided the answer. The problem was that those teachers did not allow for enough mental-processing time for the learners to determine the answer. Consequently, none of those students benefitted from fully thinking through the question on their own. Increasing the wait time after a question is asked leads to more students having better and longer answers with better reasoning supporting the answer (Hugo, 1989; Meins, 1991). Another flaw in a teaching tactic is the assumption that higher-order thinking skills can be fully developed simply by asking higher-order thinking questions. Although asking these questions contributes to learning higher-order thinking skills, other techniques, such as supporting metacognitive strategies, can be used to help develop higher-order thinking skills yet further (Meins, 1991). A further detriment is that the majority of questions that many teachers ask their students are at a lower-order thinking level, for example closed-ended questions requiring a yes or no answer (Thomas, 1999b). Consequently, due to problems with teaching techniques, higher-order thinking skills are not developed as much as they should be.

Another concern is that some school districts require students to complete standardized tests that focus on lower-order thinking skills (McNamee, 2011; Sondel, 2009). Educational evaluators tend not to question whether these standardized tests actually assess what should be taught, in other words higher-order thinking skills (Hugo, 1989; Kaplan, 1997). Standardized tests may focus on lower-order thinking skills since it is inherently harder to assess higher-order thinking skills and assessing higher-order thinking skills can be prone to subjectivity (Burkhart, 2006; Hugo, 1989). According to McNamee (2011) and Sondel (2009), due to the pressure of having students perform well on fact-based standardized tests, more class time is spent on reading to the detriment of other courses and skills, such as critical thinking. As well,

standardized tests tend to lead teachers towards teaching lower-order thinking skills, when the tests are a focus of their accountability (Burkhart, 2006; McNamee, 2011). Since, standardized tests often consist of fact-based, multiple-choice questions, teachers may limit the bulk of their classroom assessments to similar multiple-choice questions to help prepare their students for the standardized tests (Donahoe, 2001). When standardized testing has an emphasis on lower-order thinking skills, the importance of higher-order thinking skills may be minimally reinforced. This could influence learners to not spend as much time practicing or studying higher-order thinking skills and not transferring the skills to other situations (Semper Scott, 2005).

Given the above factors, it is not surprising that teachers and the education system itself have continually been criticised and are under pressure to improve the teaching and learning of higher-order thinking skills. In response, many resources and strategies have been implemented, some involving substantial investments. In some schools, direct interventions in training teachers have helped improve the teachers' ability to develop the learners' higher-order thinking skills (Wilber, 2000). As compared to traditional classrooms of the past, where memorization was the norm, many teachers in today's classrooms do address higher-order thinking skills (Gammill, 2000). According to Gruberman (2005), "In most classrooms there is some evidence of problem solving, evaluation, extrapolation, analogical reasoning, and decision making" (p. 6). In general, as Kaplan (1997) stated, many "departments of education have issued directives calling for an emphasis on cognitive skills from kindergarten through high school and innumerable colleges and universities have instituted required courses in creative and critical thinking (Ruggiero, p. ix)" (p. 28). In some fields, such as pilot training and nursing, there is a requirement for higher-order thinking skills to be taught (Carwie, 2010; Mackenburg-Mohn, 2006; Toth, 1996). Similarly, in some regions, such

as the State of Georgia in the United States of America, the curriculum has changed so that the emphasis is on conceptual understanding. In other words, there is a requirement for teaching higher-order thinking skills, as opposed to simply covering material (Bradberry-Guest, 2011). According to Kaplan (1997), the

Commonwealth of Massachusetts has made clear its plan to assess student achievement in ways that reflect higher order thinking skills. No longer will the rote recall multiple choice question of the past be found on the M.E.A.P. or M.C.A.S. to come. A combination of multiple choice and open-ended questioning will tap the thinking of our students. Competency will determine graduation for future students (p. 27),

where M.E.A.P. and M.C.A.S. refer to standardized exams of the state of Massachusetts in the United States of America. Similarly, the “Rhode Island Professional Teacher Standards indicate that critical thinking and higher-order thinking skills should be addressed in classrooms” (Jeremiah, 2012, p. 6). These changes in graduation requirements have led to significant efforts in developing the students’ higher-order thinking skills. In spite of the envisioned success of changes like these throughout the world, students have graduated without enough of the higher-order thinking skills that they need in the workplace and life itself (Jeremiah, 2012).

The relatively few gains in the learning of higher-order thinking skills by traditional means dictate that specific interventions are needed. Fortunately, research has shown that higher-order thinking skills can be taught through dedicated educational interventions (Abdellatif, 2008; Campbell, 2000; Cotton, 1991; Hendricks, 1998).

In agreement with Enniss (2006) and Stambaugh (2007), Hall (2005) stated that direct interventions are needed as research showed that “students tend to operate at the lower levels of critical thinking and only progress through higher levels when challenged to do so by the instructor” (p. 95). According to Burkhart (2006), Jeremiah (2012), and Wruck (2010), students tend not to improve higher-order thinking skills when there is no explicit intervention in place. This is a distinct problem because

individuals who have not developed higher-order thinking skills may debate on issues they know little or nothing about, be close-minded to new ideas, not recognise when they need more information to make a conclusion, be unable to determine when a conclusion must be true as compared to might be true, not appreciate that others may define things differently, be unaware of their own reasoning errors, and fail to separate emotional thinking from logical thinking (Hugo, 1989). As well, students may not even recognize when higher-order thinking skills are needed (Fanetti, 2011). This is congruent with Commeyras (1991) who stated that it is common to find individuals that accept information without critically analyzing it, make incorrect conclusions, think in biased ways, and find information to support their beliefs while ignoring information that goes against their beliefs. Commeyras suggests that extensive training must be provided to overcome these higher-order thinking shortcomings.

1.1 Problem Statement

The problem arises because many students leave the school system with inadequate higher-order thinking skills. In 2001, von Glasersfeld advocated for the need of students to develop higher-order thinking skills by stating, “the deeper purpose of school is to foster independent thinking” (p. 2). In other words, it is more important to teach students how to think as opposed to what to think. In yet further support, some experts feel that developing higher-order thinking skills is more important than learning factual information (Sondel, 2009; Thomas, 1999b). For example, if facts are forgotten, in many cases an individual only needs to know how to find the needed information. However, if a person does not have the thinking skills to solve a problem, the person will not likely have any easy solution for the situation.

Regardless of the need for higher-order thinking skills to be applied to numerous life situations, many teachers have focussed on lower-order thinking skills, such as by

transmitting facts to their students, rather than emphasizing higher-order thinking skills (Shinnick 2010; Thomson, 2009; Wruck, 2010). There are a number of reasons why teachers have emphasized lower-order thinking skills. For example, some teachers have few skills or no skills in how to teach logical-thinking skills (Almatrodi, 2007; Burkhart, 2006), there were inadequate resources (Rigmaiden, 2011), and, as discussed above, standardized testing (McNamee, 2011; Sondel, 2009). As a consequence of being taught lower-order thinking skills, students have mainly been required to memorise facts (Bessick, 2008; Clark, 2005; Hunter, 2010; Liu, 2006), which stymies the cognitive development of individuals since memorising facts does not lead to the development of higher-order thinking skills (Toth, 1996; Wruck, 2010).

Given the barriers, one cannot assume that the problem of individuals not having developed enough higher-order thinking skills will be rectified in the near future. Consequently, interventions are needed. One possible partial solution to the problem is developing stand-alone educational software or paper-based materials. However, more research needs to be done in this area. There are many reasons why more research is needed.

There has been little research on teaching higher-order thinking skills, particularly for interventions delivered in the stand-alone modes of educational software and paper-based materials. Historically, there has been a dearth of research on teaching higher-order thinking skills within any context. “MacMillan found only 27 studies between 1950 and 1985 that used critical thinking as the dependent variable” (Miller, 2003, p. 13). Of the relatively small amount of research involving the teaching of higher-order thinking skills that has been done, most of the studies have focussed on classroom practices (Semper Scott, 2005), rather than the stand-alone educational-software and paper-based interventions of this research. In particular, there is little

research regarding the teaching of higher-order thinking skills that assesses comparable interventions.

It has not been easy for researchers to conduct studies on the effectiveness of teaching higher-order thinking skills via educational software because educational software has often focused on lower-order thinking skills and drill-and-practice (Astleitner, 2002; Kreyche, 2002; Solomon, 2008), and, as Solomon (2008) stated about commercially-produced educational software, “Many of these products do not follow proven educational theory, and are lacking in the essentials to induce learning” (p. 1).

At the time of this writing, there were relatively few studies that have evaluated whether instructionally-sound, stand-alone educational-software interventions can be used to effectively teach higher-order thinking skills (Lafferty, 1996; Vowels, 2008). Most of the research on educational software has focussed on traditional test scores or cost-effectiveness (Leiker, 1993; Mintz, 2000; Wenglinsky, 1998), rather than higher-order thinking skills. Many studies presented qualitative or anecdotal results (Shinnick 2010). Consequently, there is a particular need for the quantitative results of this research.

With respect to stand-alone paper-based interventions being used to teach higher-order thinking skills, there is minimal conclusive research. A considerable portion of the related research has revolved around traditional classroom practices where the interventions include more than paper-based materials (Semper Scott, 2005), such as discussions. Like the research regarding educational software, much of the research regarding thinking skills has focused on lower-order thinking skills (Scher, 1999).

Many of the studies regarding how effectively stand-alone resources teach higher-order thinking skills have focussed on post-secondary school subjects (Burkhart,

2006). Consequently, there are only a small number of studies regarding higher-order thinking skills in subjects of comparable ages to this research. Only a fraction of those studies specifically addressed the narrower category of logical-thinking skills. According to Mains (1997), there are only a few studies in the area of logical thinking, and most of those addressed skills specific to a course. Even fewer researchers have addressed the issue of whether gains in higher-order thinking skills taught through educational-software or paper-based interventions transfer to other problems. Similarly, there is a paucity of research comparing educational software interventions to paper-based ones.

The literature provided few details regarding the instructional strategies used in interventions (Roop, 2002; Wruck, 2010). Most of the reviewed dissertations only vaguely described the instructional strategy utilised or did not describe it at all. This has led to uncertainty in how to teach higher-order thinking skills and the more specific logical-thinking skills, since, as Hurte (2004) stated, “few studies have explored which teaching methods are most effective in enhancing critical thinking” (p. 2). Also, Roop (2002), Stambaugh, (2007), and Wruck (2010) stated that there are few studies that have assessed specific instructional strategies. Yet a further problem stems from many studies using more than one technique to teach higher-order thinking skills (Hurte, 2004). For example, many of the studies that assessed the effectiveness of paper-based materials also included the subjects discussing the material. McCormick (1988) had a similar finding as he stated that most of the existing higher-order thinking skill interventions entailed reading, writing, and discussion. The researchers did not determine the amount of gain from each component in the intervention. Consequently, it is not known how much impact each factor or factors had on learning higher-order

thinking skills. In contrast, the report of this study provides details regarding the instructional strategies used.

Given the vast number of higher-order thinking skills that could be taught, this study focused on teaching logical-thinking skills for a number of reasons. Enhancing logical thinking would support learning mathematics (Wolfe, 1999), which is applied in numerous subjects and fields. Some teachers have few skills or no skills in how to teach logical-thinking skills (Almatrodi, 2007). Compounding the lack of skills, in the province of British Columbia, Canada, there were few resources for teaching logical-thinking skills because there was no provided curriculum (B. Johnson, personal communication, June 14, 2015). There are few studies focusing on higher-order thinking skills in subjects of comparable ages to this research and only a fraction of those studies specifically addressed the narrower category of logical-thinking skills. Hurte (2004) stated that there is uncertainty in how to teach higher-order thinking skills. By extension and confirmed through a literature review, there is little known about the more specific logical-thinking skills. Mains (1997) stated that there are few studies regarding logical thinking, and most of the studies addressed course-specific skills as opposed to generic skills.

Through numerous detailed searches, no studies were found that completely paralleled this research. A majority of the studies assessed traditionally-delivered materials and different types of higher-order thinking skills rather than specifically measuring logical-thinking skills. Of the studies that evaluated logical-thinking skills, none measured the same skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning. Some of the existing research is different because higher-order thinking skills specifically addressed the curriculum, such as in nursing, mathematics, or economics, rather than teaching generic logical-thinking skills. A

portion of the studies did not entail a stand-alone intervention. Many of the studies involved older students who were in secondary and post-secondary school. Few studies involved grade six and seven students, who were the subjects of this study. Only three studies were found that compared an educational-software intervention to a paper-based intervention, as was done in this research. Only a few researchers measured the transfer of learning of higher-order thinking skills. The literature provided little regarding instructional strategies for teaching higher-order thinking skills. The lack of studies found regarding instructional strategies or instructional design is consistent with Wruck (2010) who stated, “there is virtually no research on the instructional design aspect of strategies used in course development” (p.36). Consequently, the instructional strategies and activities within the interventions created for this research are unique. However, some techniques, such as providing elaborate feedback, are found in other studies.

Table 1.1

Summary of the Research Gap

Skill	Comments Regarding Research on Educational Software	Comments Regarding Research on Paper-based Materials
Classification	<ul style="list-style-type: none"> • No studies were found. 	<ul style="list-style-type: none"> • No studies were found.
Analogical Reasoning	<ul style="list-style-type: none"> • One quantitative study was found with grade seven subjects. Transfer of learning was not assessed. • One quantitative study was found with grade four to eight subjects. The intervention was not stand-alone. Transfer of learning was assessed. • Studies within a meta-analysis. The interventions were not stand-alone. Transfer of learning was not assessed. • Details regarding instructional strategies were only found within interventions taught through traditional means. 	<ul style="list-style-type: none"> • One study was found with grade one subjects. Assessment was done both quantitatively and qualitatively. The skill was defined differently. Transfer was not assessed.

Table 1.1, continued		
Sequencing	<ul style="list-style-type: none"> • One quantitative study was found with kindergarten subjects. The skill was defined differently. Transfer of learning was assessed. 	<ul style="list-style-type: none"> • No studies were found.
Patterning	<ul style="list-style-type: none"> • No studies were found. 	<ul style="list-style-type: none"> • No studies were found.
Deductive Reasoning	<ul style="list-style-type: none"> • One quantitative study was found with grade seven subjects. The skill was defined differently. Transfer of learning was not assessed. • Studies were found within a meta-analysis. The interventions were not stand-alone. Transfer of learning was not assessed. • One quantitative study was found with post-secondary students. The intervention was not stand-alone and the skill was defined differently. Transfer of learning was not assessed. • One quantitative study was found with post-secondary subjects. The skill was defined differently. Transfer of learning was not assessed. 	<ul style="list-style-type: none"> • No studies were found.

Table 1.1 presents details regarding the existing research addressing educational software and paper-based materials that aim to teach the specific logical-thinking skills assessed within this study. For educational software interventions, no research was found for the classification and patterning skills. A small amount of research was found regarding analogical reasoning although no study had subjects in both grade six and seven. One study was found that taught a sequencing skill although it was for kindergarten students and the skill was defined differently. Some research was found for deductive reasoning albeit none addressed the skill defined in the same way with both grade six and seven students. No study provided details on instructional design. The studies did not qualitatively assess the materials, and only two studies assessed transfer of learning. With respect to paper-based materials, only one study was found that

addressed one of the specific skills of this study, although it was defined differently and transfer was not assessed.

In short, no studies were found that assessed and compared gains in the same generic logical-thinking skills and the transfer of those skills taught through a standalone educational software or paper-based mode to grade six and seven students. This research helps to fill some of the above gaps and aids in confirming the findings of some of the existing research.

1.2 Objectives of the Study

This study was guided by two objectives. The first objective was to investigate whether there were any differences between the effectiveness of the paper-based materials and educational software in teaching logical-thinking skills and transferring those skills to new problems. The second objective was to assess the efficacy of the paper-based materials and educational software in teaching logical-thinking skills and transferring those skills to new problems.

1.3 Research Questions

To achieve the above objectives, the following research questions guided the study:

1. Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?
2. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?

3. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?
4. Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?
5. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?
6. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?
7. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

1.3.1 Dependent and Independent Variables

The dependent variable was logical-thinking ability. The dependent variable was based on pre-test and post-test scores. The independent variable was the instructional intervention. The instructional interventions were delivered via either educational software or paper-based materials.

1.4 Significance of the Study

This study is significant in that it contributes to theory, closes gaps in the literature, and benefits teachers and learners.

Through answering the research questions, this study will help to confirm whether the newly-created Combined Instructional Design and Development Model can be an effective model for creating stand-alone instructional resources that aim to teach logical-thinking skills.

The literature provides little information about how to teach logical-thinking skills (Roop, 2002; Wruck, 2010). Most researchers have not included enough details for another researcher to be able to use the instructional strategies of the intervention to create other instructional resources. This is a reason why the instructional strategies of this research are unique. This report provides detailed information on the instructional strategies used to teach logical-thinking skills. Since the principles and instructional strategies used for teaching the logical-thinking skills are generic, the principles and instructional strategies described in this study can be used to provide insights into how other stand-alone educational-software programs and paper-based materials should be designed to teach other logical-thinking skills or the same generic logical-thinking skills to other age groups. This is important for educational software as Astleitner (2002) said, “It is an open question, whether CD-ROM- and Internet-based instruction can successfully promote critical thinking” (p. 53). The instructional strategies of this research are also important for traditional delivery methods, which can include paper-based materials, as Walker (2001) stated, “The question still remains as to whether critical thought can be taught and enhanced through classroom instruction” (p. 13).

As indicated above in Table 1.1, this study fills some gaps in the literature. No study has addressed the same five sub-skills (classification, analogical reasoning, sequencing, patterning, and deductive reasoning) of logical-thinking ability. Specifically, one study was found (Hendricks, 1998) that assessed a classification skill, albeit Hendricks defined the skill differently and the intervention taught subjects of

different ages via traditional means. A number of research studies were found that assessed analogical reasoning but none of these studies were with both grade six and seven subjects and most of the studies used traditional teaching methodologies rather than standalone educational software and paper-based materials. Two studies were located on sequencing skills. In one of the studies, the skill was taught through an educational software intervention with kindergarten students (vonStein, 1982) and in the other study the skill was taught through traditional methods with grade one students (Hendricks, 1998). The sequencing skills were taught at a much simpler level of difficulty than this study since the subjects were much younger. No studies were discovered that addressed the same patterning skills. A number of studies were found that addressed deductive reasoning but none of them covered the same deductive-reasoning skill. As well, only three of the studies (Bass & Perkins, 1984; Shinnick, 2010; Toth, 1996) that addressed deductive reasoning used an educational software intervention and none of the studies entailed a stand-alone paper-based intervention. For the skills assessed within this research study, only one researcher assessed stand-alone paper-based materials and the focus of the study was analogical reasoning.

In general, of the studies found, very few involved grade six and seven students, three studies compared an educational-software intervention to a paper-based intervention, two studies assessed stand-alone paper-based interventions but with either younger or older subjects, and only a few researchers measured the transfer of learning of higher-order thinking skills.

The resulting stand-alone resources can benefit teachers for a variety of reasons. The resources can be immediately used by teachers who have not been trained in how to teach logical-thinking skills and for those who do not have the resources to teach logical-thinking skills. The resources can be used as a model to design other

instructional higher-order thinking skill materials. The resources can help teachers become more aware of the importance of logical thinking and cognisant of how logical thinking can be used in other situations. As well, teachers can use the pre-tests and post-tests as assessment tools.

The resulting stand-alone resources can support the many learners who receive little or no training in how to think logically, particularly in areas where rote memorization is common. For example, Diep (2011) stated that in Vietnam “both teachers and students have an educational background based almost exclusively on rote memorization” (p. 98) and Soeherman (2010) said that “most higher education settings in Indonesia are arranged in the traditional mode wherein teachers lecture in class and students are expected to memorize the course content for examinations (Ajisuksmo & Vermunt, 1999)” (p. 4). The resources of this research can be used during school time, be assigned as homework, or be used independently of the school system itself.

1.5 Limitations of the Study

This study has limitations that can impact its usefulness or transferability to other situations. The limitations include only one elementary school in a large urban area of a developed country participated in the study, only grade six and seven students participated in the study, the results only relate to the specific logical-thinking skills taught (classification, analogical reasoning, sequencing, patterning, and deductive reasoning), as opposed to other higher-order thinking skills, the skills transferred to other areas that were assessed were of the near-transfer variety, there is a lack of reliable tools for measuring specific logical-thinking skills (Abrami, 2008; Morey, 2008), and assessing logical thinking is problematic (Morey, 2008). As Ellingwood (1999) stated, measurements of the mind are imperfect because thinking cannot be directly observed.

The study took place in the city of Burnaby (a large urban area), Canada (a developed country). In Canada, the Federal government allocates funds to each province and territory to fund their respective public education systems as they deem appropriate. Since the money is used to fully fund primary schools (for five to twelve year old students) and secondary schools (for thirteen to seventeen year old students), primary and secondary school education is free, unless a parent or guardian chooses to send a child to a private school. In general, primary and secondary public school teachers in Canada are highly trained. To qualify as a teacher, an individual typically completes a four-year Bachelor of Education degree or earns another degree and then takes a one to two-year teacher training program. The teacher training programs are regulated and must meet standards with respect to their graduate's knowledge, skills, and professional conduct.

Being qualified as a teacher in British Columbia (the province where this research was conducted), Canada, does not automatically give one the skills to teach logical thinking. One cannot earn a provincial designation in teaching logical-thinking skills or specialize in those skills because there are no provincial programs that provide those skills. Although there are post-secondary courses that focus on teaching gifted children, these courses do not specifically address strategies for teaching logical-thinking skills. Advanced degrees can be earned in philosophy, however, these programs do not provide the skills needed for an individual to teach logical thinking. As a result, skills for teaching logical thinking can come through taking courses in teaching gifted children, experience in teaching gifted children, experience and training in teaching mathematics, as mathematics is a subject that intrinsically requires logical thinking to solve problems (Wolfe, 1999), being trained in using logic, and being taught mathematics. The knowledge acquired must then be employed to create instructional

materials that teach logical thinking because there was no provided syllabus for teaching logical-thinking skills in the province of British Columbia, Canada (B. Johnson, personal communication, June 14, 2015).

1.6 Definitions

This section provides the definitions needed for the construct of this study as well as other terms. Some of the definitions are discussed in detail in chapter 2. Acronyms are also defined.

1.6.1 Definitions

Logical thinking, as defined for the construct of this study, entails the skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning. (The broader concept of logical thinking is discussed in chapter two.)

Classification is a logical-thinking skill of determining which word, from a list of words, has the same thing in common as three given words.

Analogical reasoning is a logical-thinking skill of discovering a specific similarity between a given pair of words and using that similarity to match another given word to another word within a list of words.

Sequencing is a logical-thinking skill of determining a repeating pattern within a sequence of numbers to predict the next two numbers in that sequence.

Patterning is a logical-thinking skill of being able to search for a pattern in an initial series of examples that a second series of examples do not contain, to determine which examples in a third series match the common pattern of the first series.

Deductive reasoning is a logical-thinking skill that requires subjects to draw conclusions based on given information, then draw new conclusions based on the current information, and repeat that process until the problem is solved.

Transfer of learning occurs when skills that are developed through an intervention can automatically be applied in another area (Lafferty, 1996). With respect to this research, the transfer of learning assessed is of the near-transfer level.

Direct learning scores refer to the scores from test questions that were based directly on the content taught to the experimental groups.

Transfer learning scores refer to the scores from test questions that were not based directly on the content taught to the experimental groups.

Total scores refer to the cumulative total of scores on each specific logical-thinking skill test, where each specific test assessed a classification, analogical-reasoning, sequencing, patterning, or deductive-reasoning skill.

1.6.2 Acronyms

For brevity, a few acronyms are used.

- “**ESG**” refers to the educational-software intervention group.
- “**PBG**” refers to the paper-based intervention group.
- “**CG**” refers to the control group.

1.7 Assumptions

There were a number of assumptions associated with this dissertation. It was assumed that:

- The reviewers were capable of evaluating the materials with respect to providing an opinion on whether the instructional materials were appropriate for academically weak through strong, grade six and seven students, determining if the materials had the attributes to teach effectively, deciding if the instructional strategies would effectively enable the students to learn the skills, verifying the content, pre-tests, and post-tests in regards to accuracy

and completeness, correct answer(s), and whether each incorrect answer was plausible, and assessing the user-interface of the educational-software intervention.

- Each pilot student worked through every page or screen of the paper-based or educational-software intervention that he or she received and noted any spelling or grammatical error, text that did not make sense or could be written more clearly, disagreement with an answer, and problem in the user-interface of the educational-software intervention.
- The subjects had the required English literacy ability to learn from the resources.
- The subjects learning from the educational software had the necessary computer-literacy skills.
- In these self-paced interventions, learners can self-assess themselves well enough to know what they need to do and are mature and responsible enough to make their own effective decisions with respect to setting a pace that reflects their ability to comprehend the material, repeating activities and reviewing as needed, and proceeding in a sequence that will help them learn the material.
- The subjects tried hard to learn from the resources.
- Gains in logical-thinking skills can be accurately measured.
- The limitations of testing with multiple-choice questions, for example being weak at recognizing the full expression of higher-order thinking skills such as the attributes of “open-mindedness or drawing cautious solutions (Ennis, 1993)” (Lee, 2008, p. 27), was not relevant for the classification, analogical-

reasoning, sequencing, and patterning logical-thinking skills, which were assessed via multiple-choice questions.

- The time between each pre-test and post-test ranged from one to five weeks.

It was assumed that if there was an effect due to the lapse of time, each group would likely have been affected in a similar way.

1.8 Summary

The first chapter of this report, the introduction, covers the background of the study, problem statement, objectives of the study, research questions, significance of the study, limitations of the study, definitions, and assumptions. These sections present reasons why students did not graduate with the higher-order thinking skills that they needed in the workplace and life, the need for this research, and what the research aimed to accomplish. The research was designed to first qualitatively assess whether the educational software and paper-based materials had the attributes to teach logical-thinking skills and then quantitatively assess the effectiveness of the interventions, using a pre-test, post-test, experimental design. Specifically, the quantitative component of the study intended to compare the logical-thinking skills of subjects who were taught through educational software to those who were taught through closely-matched paper-based materials to a control group participating in unrelated activities, and the efficacy of the learning materials.

Chapter 2

Literature Review

2.0 Introduction

Researchers have provided few details with respect to a theoretical framework for developing materials that teach higher-order thinking skills. In other words, there is no clear method for effectively teaching higher-order thinking skills or the more specific logical-thinking skills. As well, there has been little research on the effectiveness of teaching higher-order thinking skills within any context, let alone for the narrower category of logical-thinking skills, and even less research if the factors of being taught in a stand-alone mode and the subjects being grade six and seven students are considered. A major portion of the related research has focused on traditional classroom practices (Semper Scott, 2005), test scores, (Leiker, 1993; Mintz, 2000; Wenglinsky, 1998), the cost-effectiveness of the intervention (Leiker, 1993; Mintz, 2000; Wenglinsky, 1998), lower-order thinking skills (Scher, 1999), and/or post-secondary school subjects (Burkhart, 2006). Only a small number of researchers have addressed the issue of whether higher-order thinking skills taught through educational-software or paper-based interventions transfer to other problems. This overall lack of research was alarming since it was well known that there was a deficiency in the level of higher-order thinking skills that graduating students attain (Burkhart, 2006; Lee, 2008). This led to the objectives of the study and the research questions.

Based on the objectives of the study and the research questions, a number of topics are discussed within this literature review. This literature review presents a

discussion of thinking skills with subtopics of higher-order and lower-order thinking skills, logical-thinking skills, critical-thinking skills, creative thinking skills, divergent-thinking skills, convergent-thinking skills, and metacognition skills; learning theories with sub-topics of cognitive development and related research, long-term and short-term memory, constructivism, practice and feedback, metacognition, and motivation; instructional design with sub-topics of instructional development cycle models, Gagné's Nine Events of Instruction, how higher-order thinking skills can be taught, and instructional strategies for teaching analogies; the transfer of learning; screen and interface design; the assessment of thinking skills; findings on teaching higher-order thinking skills using educational software and using paper-based materials; findings for comparable interventions; research on the transfer of thinking skills; and the theoretical framework.

Although this study focused on logical-thinking skills, defined as the skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning as described below, much of the research discussed below is based on broader constructs such as critical thinking and higher-order thinking skills since there is extremely little research that encompasses the narrower topic of teaching logical-thinking skills.

2.1 Thinking Skills

Although thinking skills means different things to different people (Gruberman, 2005), thinking, as defined by Enniss (2006), is the “systematic, purposeful mental activity in which an individual engages as s/he seeks to make sense of and reach for meaning in text in relation to acquiring advanced knowledge (Ruggiero, 1984). A natural function of the brain; what the brain naturally does (Smith, 1990)” (p. 12). In a simplistic way, thinking has been described as “those cognitive processes by which knowledge is acquired” (Gruberman, 2005, p. 34). Thinking has also been defined as a

“set of basic and advanced skills and subskills that govern a person's mental processes. These skills consist of knowledge, dispositions, and cognitive and metacognitive operations” (Lamb, 2001, p. 3). With respect to “advanced” skills, researchers have used the generic terms: critical thinking and higher-order thinking skills (Gruberman, 2005). To encapsulate “basic” skills, the term lower-order thinking skills had been used by researchers, such as Burkhart (2006) and Stambaugh (2007).

To more fully describe higher-order thinking skills, some major categories of these skills are discussed. Of these skills, logical-thinking skills needed to be narrowly defined to provide the requisite operational definitions used within this study.

2.1.1 Higher-order and Lower-order Thinking Skills

There is a problem in that the literature has presented many definitions of critical thinking and by extension higher-order thinking, of which logical thinking can be considered a subset (Lamb, 2001), partly because there is no wide consensus for a definition (Jeremiah, 2012; Svenningsen, 2009; Wilson-Robbins, 2006). Experts in the field have not even agreed on whether the definition of critical thinking should be based on general skills or subject-specific skills (Stambaugh, 2007; Thomas, 1999b). A difficulty in creating a definition of critical thinking is that the phenomenon of critical thinking is complex and no single definition can fully encompass it (Huff, 1998). From a generic perspective, according to Almatrodi (2007), critical thinking takes place when abstract thought is involved and when there is concerted mental effort. Although the notion of the criteria of abstract thought and concerted mental effort is useful to a degree, the notion does not lead to a definition. As well, with respect to a definition, critical thinking has become a catchall term for a number of thinking skills and is used as a general term for higher-order thinking skills (Gruberman, 2005). This was brought into perspective by Joy Paul Guilford who identified 120 different higher-order thinking

skills, where some of the skills are dependent on other skills being developed first (Lafferty, 1996; Semper Scott, 2005). Others have suggested that there are further difficulties in listing higher-order thinking skills because some skills are identified by more than one verb (Semper Scott, 2005). Other verbs can be used at more than one level of thinking. For example, the skill of identifying can be shown by pointing to a part of a diagram or diagnosing a disease.

Bloom, Engelhart, Hill, Furst, and Krathwohl (1956) defined six levels of thinking skills that are commonly referred to as Taxonomies of Learning Outcomes. These levels are called knowledge, comprehension, application, analysis, synthesis, and evaluation, as shown in Figure 2.1. Although these skills are classified into levels, the skill levels can be considered to describe a continuum of skills ranging from simple to complex. The verbs associated with each level are measurable, and consequently can be assessed.

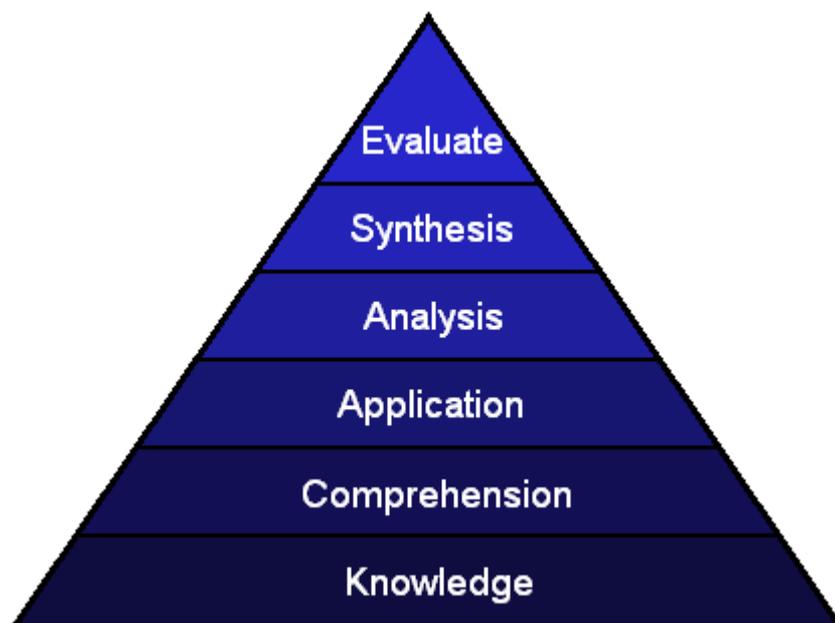


Figure 2.1 – Bloom's Taxonomy

In 2001, Anderson and Krathwohl revised Bloom's taxonomy into the hierarchical categories called remember, understand, apply, analyze, evaluate, and create, where creating is the highest skill level. This hierarchy is illustrated in Figure

2.2. Other authors, Gagné, Briggs, and Wager (1988), categorized learning outcomes into learning domains called verbal information, which entails remembering and recalling information, intellectual skills, which require learners to think, cognitive strategies, which require learners to do something original or creative, psychomotor skills, where learners use muscular actions to achieve something, and attitudes or tendencies individuals have with respect to making specific decisions or choices under stated circumstances.

Gagné et al. (1988) defined a number of sub-skills of intellectual skills. These include discriminations, which are low-level thinking skills where students simply note differences, concrete concepts, which are also low-level thinking skills that are more advanced than discriminations in that these may require students to note similarities and differences, defined concepts, which require students to group or classify objects and ideas into stated categories, rules, which are combinations of concepts, and higher-order rules, which require learners to combine more than one rule.

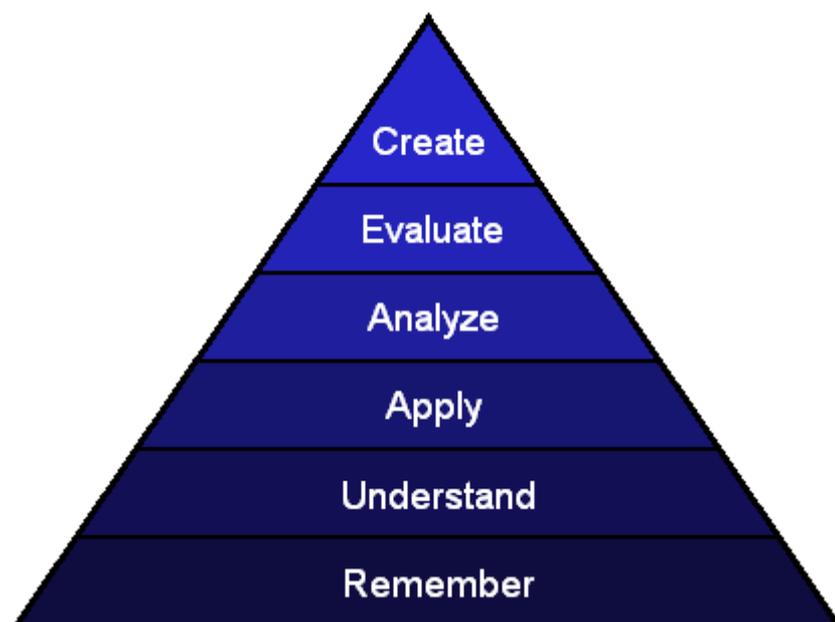


Figure 2.2 – Revised Bloom's Taxonomy

The highest level of thinking skill of Gagné et al. (1988) was the cognitive skill of doing something original or creative. This parallels Anderson and Krathwohl's (2001)

revised Bloom's taxonomy where they consider creativity to be the highest level of thinking skill, whereas Bloom et al. (1956) placed evaluation as the highest level of thinking skill and synthesis as the second highest. Creativity and synthesis are related skills, as discussed below.

Given that the definitions of higher-order thinking skills found in the literature all emphasize thinking at deeper levels (Terry, 2007), for simplicity, in this dissertation, the term "higher-order thinking skills" is used to generically describe any thinking skill of an advanced level and "lower-order thinking skills" is used to generically describe thinking skills that require less thinking than higher-order thinking skills. With respect to Bloom's taxonomy, higher-order thinking skills include analysis, synthesis, and evaluation, in an ascending order of difficulty, whereas lower-order thinking skills include knowledge, comprehension, and application (Burkhart, 2006; Jeremiah, 2012; Stambaugh, 2007). However, there is some disagreement as to the "grey" area between higher-order thinking skills and lower-order thinking skills (Burkhart, 2006). For example, some researchers, such as McDonald (2003), Rigmaiden (2011), and Walker (2001), suggested that application is a higher-order thinking skill. Within Anderson and Krathwohl's (2001) revised Bloom's taxonomy, higher-order thinking skills include analysis, evaluation, and creation, in an ascending order of difficulty, whereas lower-order thinking skills relate to understanding, remembering, and application, while noting that application was considered by some to be a higher-order thinking skill. With respect to the classification of intellectual and cognitive skills of Gagné et al. (1988), higher-order thinking skills include defined concepts, rules, higher-order rules, and creativity, in ascending order of difficulty. In the thinking skill classifications of Anderson and Krathwohl (2001), Bloom et al. (1956), and Gagné et al. (1988), higher-order thinking skills can be viewed as cognitive processes that can be used to do

something with lower-order thinking skills. In other words, lower-order thinking skills are needed as a foundation for higher-order thinking skills. For example, if a learner does not know the definitions of the words used (a lower-order thinking skill) in an analogical-reasoning question, the learner will not be able to solve those analogical-reasoning questions (a higher-order thinking skill).

2.1.2 Logical-thinking Skills

Logic is a “way of reasoning correctly, or without making mistakes, to solve problems” (Rivière, 1990, p. 13), for example, where one can make conclusions based on premises (Rivière, 1990). Similarly, Mains (1997) defined logical thinking as “reasoning in a clear and consistent manner based on earlier or otherwise known statements, events, or conditions (Mayer, 1983)” (p. 8).

Lamb (2001) stated that logical thinking and reasoning includes numerous skills such as comparison, classification, sequencing, cause/effect, patterning, webbing, analogies, deductive and inductive reasoning, forecasting, planning, hypothesizing, and critiquing. As such, for practical reasons, the construct of logical thinking for this study needed to be more narrowly defined. As an operational definition, the specific logical-thinking skills that were taught and measured through the educational-software and paper-based interventions were the skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning. Since each of the specific skills of this operational definition can be defined in different ways, each skill was defined for the context of this research study.

Classification Skill

Although no formal definition of classification skills was found in the literature, at the basic level, classification skills include the ability to learn the relationships between

foundational classes (e.g., dogs, trees, and metals) and higher-level classes (e.g., animals) that include lower-level classes (e.g., dogs, birds, and fish). A more challenging type of classification skill, called transitivity, entails the ability to determine relationships between objects (Hendricks, 1998). For example, if the first object is heavier than the second object and the second object is heavier than the third object then it can be determined that the first object is heavier than the third object. As one's classification skills develop, individuals become able to group together related concepts, such as objects, events, and ideas. This can be done by determining which concept within a group of concepts has a unique characteristic, such as by finding an identifying feature or applying probability (Hendricks, 1998).

For this research, classification is defined as the logical-thinking skill of determining which word, from a list of words, had the same thing in common as three given words.

Analogical-reasoning Skill

A characteristic of analogies is that “the second element relates to the first as the fourth element to the third” (Moran, 1989, p. 8), where one rule determines the relationship between each pair of elements (King, 2008). Pate (1989) stated that an analogy is “the process of relating information sets to each other on the basis of shared attributes (Hayes & Tierney, 1980; Tierney & Cunningham, 1980)” (p. 27). Using these definitions as a foundation, analogical reasoning entails problem-solving skills that require the ability to reason about the similarities of relations.

For this study, the logical-thinking skill of analogical reasoning is the ability to discover a specific similarity between a given pair of words and using that similarity to match another given word to a word in a list. This is similar to Wilson (1986) who stated that solving an analogy “requires matching the first pairing, termed the domain,

to the second pairing, termed the range, in order to reach a solution to the problem” (p. 8).

Sequencing Skill

Sequencing skills are those needed for determining what comes next in a series or sequence. In general, sequencing skills require the ability to identify the characteristics of neighbouring items. There are many types of sequences. These include sequences of numbers, letters, and time, positional sequences relating to rotation and orientation, causal sequences of events and activities, and any repeating sequence such as those made from colours, shapes, objects, letters, or numbers or more complex sequences made from combinations of these (Hendricks, 1998).

For this research, the sequencing skill is the logical-thinking skill of determining a repeating pattern within a sequence of numbers to predict the next two numbers in that sequence.

Patterning Skill

No formal definition of patterning skills was found in the literature, although Hendricks (1998) suggested that the sequencing skill can involve searching for patterns. For this study, patterning is not related to the sequencing skill as it is the logical-thinking skill of being able to search for a pattern in an initial series of examples that a second series of examples did not contain, to determine which examples in a third series matched the common pattern of the first series.

Deductive-reasoning Skill

“Deductive reasoning is the kind of reasoning in which one reaches a conclusion based on the premises (Garnham & Oakhill, 1994). If the premises are true, the conclusion must be true” (King, 2008, p. 10). Similarly, when defining deductive

reasoning, Walker (2001) stated that the “assumed truth of the premises purportedly necessitates the truth of the conclusion” (p. 8). Deductive reasoning can be applied to solve a variety of problems. For example, three types of deductive-reasoning skills have been described that can be used for writing proofs. These skills were called conditional reasoning, class reasoning, and ordinal reasoning, where conditional reasoning is used when conditional statements lead to making an argument, class reasoning is applied when quantifiers support arguments, and ordinal reasoning is exercised when physical relationships (e.g., weight, length, and speed) are foundations for forming arguments (Subramanian, 2005). Another type of deductive reasoning is syllogistic reasoning where individuals draw conclusions based on one or more “if-then” statements. As an example of its use, syllogistic reasoning is needed for writing computer programming code (Mains, 1997).

For this research, the logical-thinking skill of deductive reasoning requires subjects to draw conclusions based on given information, then draw new conclusions based on the current information, and repeat that process until the problem is solved.

Transfer of Learning

As it is essential to define the construct of logical thinking as used in this research, it is also important to state how “transfer of learning” was defined for this research. Shin (2002) stated that transfer of learning “happens when a learner applies skills, strategies, attitudes, and concepts he or she learned from one context to another significantly different context” (p. 58). Similarly, Lafferty (1996) indicated that transfer occurs when skills that are developed through an intervention can automatically be applied in another area. These descriptions are comparable to Meyer (2010) who extended the concept further when she stated, “Learning transfer occurs when one piece of knowledge impacts the learning of another piece of knowledge or another application

for the knowledge” (p. 4). The two types of transfer that are typically described are called near transfer and far transfer (Lafferty, 1996; Shin, 2002). Near transfer refers to when the skill learned transfers to situations that closely parallel what was taught (Meyer, 2010). Far transfer occurs when the skill learned transfers to situations that are distinctly different from what was taught (Meyer, 2010). In this research, transfer of learning was defined as near transfer since the skills learned are applied to problems that are similar to those presented in the intervention. The difference was that the transfer problems contained a concept that the subject did not get exposed to in the intervention.

2.1.3 Critical-thinking Skills

Given critical thinking has been used as a general term for higher-order thinking skills (Gruberman, 2005) and logical thinking, the focus of this study, has been considered to be a subset of critical thinking (Lamb, 2001), it was important to define critical thinking more succinctly. John Dewey provided one of the first definitions of critical thinking. As stated by Hurte (2004), “Dewey described critical thinking as involving a feeling of imbalance which spurs the act of searching for information and knowledge which will create the opposite feeling of balance” (p. 13). Many other definitions have been presented, including Enniss (2006):

Critical Thinking: A generative, creative, knowledge producing process that is ‘in everyone’s behavioral and cognitive repertoire’. The individual develops and demonstrates the ability to be reflexive, that is, to step back, examine any available evidence and then look forward to consequences. He takes into consideration more than a literal meaning of any text or situation (Smith, 1990) and (Siegal and Carey, 1989) (p. 11).

Legant (2010) defined critical thinking as “reflective analysis that is focussed on understanding an issue, creating and weighing solutions, and making informed decisions (Marzano, et al., 2001)” (p. 8). In 2008, Lee described critical thinking as “making reasonable judgements based on various sources of information, not just on

individual opinions, and trying to understand the issue at hand in deep, meaningful ways, as opposed to gaining surface level understanding” (p. 5). As a comparison, there are similarities and differences from Facione and Facione (2009) who stated that, “Critical thinking is the process of making purposeful, reflective and fair-minded judgements about what to believe and what to do” (¶1).

On a more practical level, critical-thinking skills, as described by a panel of experts, include evaluation, analysis, inference, explanation, interpretation, and self-regulation (Reid, 2010). In comparison, Enniss (2006) suggested that critical thinking includes the skills of “logic, analysis, synthesis, problem-solving, deductive reasoning, inductive reasoning, questioning, inferential thinking, reflective thinking/reflection, [and] self-motivated inquiry (Ennis, 1962; Siegel & Carey, 1989)” (p. 15). Ennis’ list of skills can be further refined based on Lamb (2001) who stated, “Critical thinking involves logical thinking and reasoning including skills such as comparison, classification, sequencing, cause/effect, patterning, webbing, analogies, deductive and inductive reasoning, forecasting, planning, hypothesizing, and critiquing” (p. 1). Based on the above definitions and lists of skills, there is a distinct connection between critical thinking and logical thinking, where logical thinking can be thought of as a subset of critical thinking.

2.1.4 Creative Thinking Skills

As Anderson and Krathwohl (2001) and Gagné et al. (1988) stated, doing something original or creative, is the highest level of thinking skill. According to Lamb (2001), “Creative thinking involves creating something new or original. It involves the skills of flexibility, originality, fluency, elaboration, brainstorming, modification, imagery, associative thinking, attribute listing, metaphorical thinking, and forced relationships” (p. 1). Cotton (1991) described creative thinking as a “novel way of

seeing or doing things that is characterized by four components— FLUENCY (generating many ideas), FLEXIBILITY (shifting perspective easily), ORIGINALITY (conceiving of something new), and ELABORATION (building on other ideas)” (p. 3). Creating has been described as the ability to place “elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure” (Anderson & Krathwohl, 2001, p. 68). For example, students can show creativity by hypothesizing, designing something new, determining a new way to complete a task, and generating a number of reasons that explain something observed (Stambaugh, 2007). Similarly, synthesis can be shown by arranging or combining information in a new way (Jeremiah, 2012) or making “connections between seemingly unconnected concepts (Schleicher, 2010)” (Jeremiah, 2012, p. 12). Orabuchi (1992) had a comparable definition, whereby the skill of synthesis was defined as “the ability to create a new whole by putting components or parts, or elements together” (p. 10). Orabuchi essentially used the terms “synthesis” and “create” synonymously. This suggests that the skills are indeed related and also creativity, as used by Anderson and Krathwohl (2001), is essentially the same skill as synthesis, as utilized by Bloom et al. (1956).

Although it has been argued that creative thinking is the highest level of thinking skills, creative thinking could be described as being one of many critical-thinking skills given that critical-thinking has been used as a generic term.

2.1.5 Divergent-thinking Skills

According to Dhingra and Sharma (2012), “Divergent thinking is the ability to produce unusual and original ideas and to take an idea and spin out elaborate variants of the idea” (p. 155). Gallavan and Kottler (2012) stated that divergent thinking requires the “processes of breaking apart or deconstructing a topic into parts and then generating as many creative, original, and varied productions as possible” (p. 165) and “divergent

thinking entails imagination, curiosity, flexibility, complexity, and intellectual risk-taking associated with brainstorming an array of feasible answers to open-ended questions or solutions to challenging problems or situations” (p. 165). Divergent thinking is related to creative thinking in that one’s divergent-thinking ability is affected by one’s skills in originality (the ability to construct new ideas), fluency (being able to generate numerous ideas), flexibility (the ability to create different kinds of ideas), and elaboration (being able to build upon current ideas) (Dhingra & Sharma, 2012). Gallavan and Kottler (2012) expanded on the above list of skills when they stated that divergent thinking also includes association fluency (where one writes new content based on concepts and vocabulary learned in other areas), expressional fluency (being able to detach oneself from current ideas, which enables one to accept new ideas), adaptive flexibility (the ability to deconstruct information to enable detailed analysis and understanding), and sensitivity to problems (the skill of realizing that since there can be numerous perspectives on a given problem, different resources need to be applied to solve the problem).

Based on the varied types of thinking involved, divergent thinking can be applied to a wide range of situations. For example, divergent thinking can be used in many instances where creativity is needed (Dhingra & Sharma, 2012; Gallavan & Kottler, 2012; Gilhooly, Georgiou, Garrison, Reston & Sirota, 2012; Kleibeuker, De Dreu & Crone, 2012), generating analogies, listing other uses of objects, identifying common characteristics, providing multiple solutions to open-ended problems, generating tentative explanations, and inventing (Gallavan & Kottler, 2012; Gilhooly et al., 2012; Joshua, 2014; Kleibeuker et al., 2013).

2.1.6 Convergent-thinking Skills

Joshua (2014) postulated, “Convergent thinking refers to the ability to come up with a single but correct solution to a given potential or actual problem (Santrock, 2004)” (p. 159). Similarly, “Convergent thinking refers to the processes of arriving at one single answer, solution, or conclusion” (Gallavan & Kottler, 2012, p. 165). Kleibeuker et al. (2013) stated similar characteristics when they defined convergent thinking as an “analytical and evaluative thinking mode, associated with discovering relations among information, and represents the capacity to quickly focus on the one best solution to a problem (Guilford, 1967; Gaborra, 2010; Runco, 2004)” (p. 3). Based on Crone’s definition, there is a parallel between convergent thinking and critical thinking in that critical thinking includes the skills of analysis and evaluation, as suggested by Reid (2010).

In comparing divergent thinking and convergent thinking, divergent thinking generates numerous ways to solve a problem while, in contrast, convergent thinking entails analysis that leads to finding the correct answer to a problem. Divergent thinking can involve creativity and novelty in solving problems while convergent thinking tends to have a best path to a solution. These differences can be viewed as strengths if convergent and divergent thinking are both used to solve problems, in that creativity combined with evaluation has the potential for better solutions. For example, after many solutions are generated via divergent thinking, convergent thinking can be used to determine the optimal solution (Barak, 2009; Cropley, 2006). In support of the need for both convergent and divergent thinking, Wulun (2007) suggested that scientific development and discoveries depend on both of these types of thinking.

2.1.7 Metacognition Skills

Metacognition is an individual's thinking about his or her own thinking. Metacognition consists of metacognitive knowledge and strategies. Metacognitive knowledge concerns a person's beliefs about him or herself (e.g., his or her ability or motivation to complete a task), task variables that relate to the nature of the task and the approach one should take with the task (e.g., knowing that a lot of practice and feedback is needed to learn how to solve complex problems), and strategy variables of knowing what is needed to complete the task (e.g., allowing more time for large tasks, such as writing an essay). Metacognitive strategies relate to planning what needs to be done (e.g., defining a learning goal), monitoring one's progress in achieving that goal, evaluating one's success in achieving the goal, and modifying one's strategies based on the results of the evaluation, particularly when one believes that he or she can influence the results. For example, a student can decide what to spend more time on, what to study next, and what actions can lead to increased success. It is commonly assumed that metacognition helps student performance (Arslan & Akin, 2014; Bessick 2008; Shin, 2002). Metacognition is an important part of one's thinking skills, particularly with logical reasoning because success in logical reasoning depends on metacognitive skills. For example, students need to identify errors that they make so that they can adjust their strategies (Baylor & Kozbe, 1998).

Summary: Thinking Skills

Although thinking skills have been defined in numerous ways, from a practical perspective, the generic terms of higher-order thinking skills and lower-order thinking skills have been used to differentiate between levels of thinking. In general, higher-order thinking refers to thinking skills, such as analysis, synthesis, and evaluation, that are deeper or more advanced than lower-order thinking skills. Lower-order thinking

skills include basic knowledge and comprehension. There are numerous broad categories of higher-order thinking skills. These categories include the skills of logical thinking, critical thinking, creative thinking, divergent thinking, convergent thinking, and metacognition. Like higher-order thinking skills, critical thinking has been used as a generic term to include any skill requiring deep thinking. Many of the broad categories of higher-order thinking skills are comprised of numerous kinds of skills. For example, logical-thinking skills include classification, analogical reasoning, patterning, sequencing, and deductive reasoning.

2.2 Learning Theories

This section provides a review of relevant theory regarding the foundations of learning theory. Cognitive development is examined as it is important to know whether the grade six and seven subjects of this study are mentally capable of learning the logical-thinking skills taught in the interventions. As well Vygotsky's Zone of Proximal Development theory is discussed. With respect to cognitive development, a brief summary of the findings in the literature are presented. This section then examines how short-term and long-term memory relate to learning. After this, constructivism, practice and feedback, metacognition, and motivation are explored as they relate to learning.

2.2.1 Cognitive Development and Related Research

It is common knowledge that individuals develop their cognitive skills at different rates and at different times. One's level of cognitive development has been shown to be important when learning higher-order thinking skills. Hurst and Milkent (1994) found that a subject's ability in predictive reasoning was dependent on their stage of cognitive development. Leiker (1993) also found that performance was significantly and positively related to cognitive development.

Piaget's theory of cognitive development

Piaget's theory of cognitive development regards the nature and development of human intelligence. This theory entails how one acquires, constructs, and uses knowledge. In his theory of cognitive development, Piaget postulated that there are four stages of cognitive development (Abdellatif, 2008; Maryannakis, 2009). The first stage, called the Sensorimotor stage, takes place from birth through to the acquisition of language, which is about the age of two. In the first stage, the child understands the world through the patterns observed through his or her actions on the world. The child constructs a sense of permanence about the world. The second stage, referred to as the Preoperational stage, occurs between the ages of two and seven. In the second stage, the child makes judgments based on his or her perceptions. By the end of the Preoperational stage, a child has developed simple reasoning skills, tends to not be systematic, does not understand hierarchical classifications, cannot readily reverse his or her thinking, and tends to be unable to deal with reciprocal relationships. The third stage, called the Concrete Operational stage, extends from the age of seven through to about eleven. In the Concrete Operational stage, individuals can correctly use logic. Some of the skills that can be mastered in the Concrete Operational stage are classification, which includes the skill of identifying things that have common traits, and sequencing, which includes the ability to recognize the relationships among numbers organized in a series. Piaget stated that the Formal Operational Reasoning stage, the fourth level of cognitive development, can begin at about the age of twelve. In the Formal Operational Reasoning stage individuals can develop skills to reason logically, solve verbal analogies, think abstractly, hypothesize, solve problems, reason deductively, systematically test solutions, and draw conclusions (Abdellatif, 2008; Burkhart, 2006; Maryannakis, 2009). However, this is a generality in that some adults do not reach the

Formal Operational Reasoning stage (Burkhart, 2006; Frear, 1997; Taylor, 1997), as advancement in cognitive development is not automatic (Loiacono, 2000). This parallels Clark's (2005) opinion when he stated,

Part of the problem about this level of thinking is when exactly are children ready (called 'readiness')? Piaget theorized that it was about at the age of twelve, others have theorized it is much earlier. One thing appears to be certain -- readiness needs to be 'forced'. I know 'force' appears to be a heavy-handed term, yet it is perhaps the best one. Why? Well, one thing is for certain -- very few individuals reach the formative stage, thus sitting around and waiting for them to reach it on their own is doing absolutely no good at all (Period of Formal Operations section, last paragraph).

Wolfe's (1999) study showed that there is variation in the age that individuals reach the Formal Operational Reasoning stage, if they reach it at all. Using the Group Assessment of Logical Thinking instrument on subjects taking college mathematics, Wolfe assessed whether there were any differences in the subjects' cognitive development. There was no correlation between age and cognitive development. However, research has shown that some children naturally reach the Formal Operational stage of cognitive development and this can be at an earlier age (Slattery, 1989).

Vygotsky's Zone of Proximal Development

The notion of subjects needing to be at the appropriate level of cognitive development to gain from a given instructional intervention is consistent with other cognitive development models, such as Vygotsky's Zone of Proximal Development. Vygotsky's Zone of Proximal Development can be described as the difference between what a learner can do on his or her own and what the learner can do with instructional support (Coffee, 2009; Reddy, 2008; Stambaugh, 2007). Based on this concept, if an individual is close to reaching the Formal Operations stage of cognitive development, they should be given the opportunity to learn skills of that level of cognitive difficulty, regardless of their age (Burkhart, 2006). This is in agreement with Ennis (2006), who

stated, “Chronological maturity is frequently not a logical indicator of critical thinking ability” (p. 5), because determining that an individual is ready to learn a skill by age alone will often be inaccurate.

Summary: Significant and Mixed Findings

A number of the research studies described below are discussed in more detail later in this literature review. The following studies, which relate to teaching elementary-school students higher-order thinking skills, had significant or mixed findings.

Working with five-year and six-year old students, Bradberry-Guest (2011) found that the experimental group could answer who, what, when, where, and why questions significantly better than the control group. King’s (2008) research showed that grade-one students could learn analogical-reasoning skills. However, the significant findings were for only one out of five stories used for assessing analogical reasoning. Petris (2009) showed that grade-three students could be taught higher-order thinking skills. Sondel (2009), Wu (2009), and Lewis (1998) found that grade-four students could be taught critical-thinking skills. On tests of analogical reasoning, Abdellatif (2008) showed that the nine and ten year-old group performed significantly better than the seven and eight year-old group as well as significantly better than the five and six year-old group. There were no significant differences between the seven and eight year-old group and the five and six year-old group, which was likely due to those students not having the level of cognitive development needed to solve the difficulty level of the analogies. Stambaugh (2007) found that inference and creative synthesis could be taught to subjects in grade three, four, and five. Katzlberger (2006) was successfully able to teach problem-solving skills to grade-six students. Etsey (2004) was able to teach grade-six students higher-order thinking skills. Brown’s (2000) study showed that

eight and nine year-old students could solve analogical-reasoning problems, if they had a relevant knowledge base to solve the problems. With subjects in grade four and five, Campbell (2000) reported significant gains in critical-thinking skills in one experimental group and a significant decrease in another experimental group. Masteron and Perrey (1999) found that analogical-reasoning skills could be taught to nine to fourteen year-old children. With students in grade four and five, (1999a) reported that no significant differences were found in abstract-relation skills, however, for grade-five students, a significant difference was found in sequential-synthesis skills. Huff-Benkoski (1998) also showed that seven and eight year-old subjects could be taught analogical-reasoning skills. Huff-Benkoski stated that “analogical reasoning steadily improves throughout the elementary, middle and high school years” (pp. 5-6). Hendricks (1998) found that grade-one subjects could be taught sequencing skills. The sequencing skills were at a simpler level of cognitive difficulty than the skills taught in this research. Hendricks, in her literature review, stated that research has shown that six to eleven year-old children can learn classification skills. Johnson (1997) showed that three out of four classes of grade-four subjects could learn analogical-reasoning skills. With grade-four subjects, Kaplan (1997) found that an intervention led to a significant improvement in a decision-making skill but not a comparing and contrasting skill. Shiah (1994) found significant gains in problem-solving skills in subjects ranging from grade one to grade six. Through a qualitative analysis of interview transcripts, Davis-Seaver (1994) found that six and seven year-old children can think critically and use logic. With subjects in grade three, four, and five, Allison (1993) found that experimental subjects performed significantly better than the control subjects in math and reading skills. Leiker’s (1993) research, with grade three and four students, led to higher scores in mathematics and higher-order thinking skills. Orabuchi’s (1992) study, with grade

one and two students, led to the experimental group scoring significantly higher on inferences, generalisations, and math problem-solving than the control group. Based on a review of research studies, Cotton (1991) concluded that analogical reasoning, logical reasoning, and inductive and deductive thinking can be taught to elementary-school children. With grade four to eight students, Swan (1990) found significant increases in skills in sub-goal formation, analogical reasoning, forward chaining, systematic trial and error, and alternative representation but not backward chaining. Duffield (1989) found that grade three and four students could learn problem-solving skills that were specifically taught. Hugo (1989) reported that grade six, seven, and eight subjects could be taught higher-order thinking skills. Moran (1989) was able to teach subjects in grade three, five, and seven both analogical-reasoning and metaphor-comprehension skills. Moran also found significant differences between age groups that are consistent with Piaget's theory of cognitive development. Pate (1989) was able to teach grade-six students analogical-reasoning skills. With grade seven and eight students, Galinski (1988) found that both groups gained in mathematical problem-solving, analysis, and synthesis ability. With grade seven subjects, Tarkington (1988) found that an experimental group gained significantly more critical-thinking skills as compared to one control group but not another control group. Judy (1987) showed that analogical-reasoning skills could be taught to grade-six students. Similarly, Wilson (1986) showed that grade-four students could be taught analogical-reasoning skills.

Summary: Findings Not Leading to Significant Gains

The following studies regarding teaching elementary-school students' higher-order thinking skills did not lead to significant findings.

McNamee (2011) found no significant differences between the groups with respect to critical-thinking skills in grade-two students while Commeyras (1991) had the

comparable findings with grade-five students. McDonald's (2003) study did not find significant differences in higher-order thinking skills with grade-six subjects. With grade-seven subjects, Baumer (2009) found no significant differences with respect to metaphorical reasoning or creativity. With subjects in grade four and five, Mintz (2000) found experimental subjects did not have any significant performance gain in critical thinking over the control group. With grade-five subjects, Rothman (2000) found that the experimental group had a higher positive trend in critical thinking but the results were not significant when compared to the control group. Ellingwood (1999) found that the experimental group of grade-one subjects had higher mean gains in higher-order thinking skills but these gains were insignificant. Lafferty (1996), with grade-four subjects, found no significant differences before and after the intervention with respect to higher-order thinking skills. With grade-seven students, Schmidt (1991) found no significant differences in weather-prediction skills. Repman's (1989) intervention with grade-seven subjects led to findings of no significant differences between the experimental and control groups in critical-thinking skills. Slattery's (1989) research did not lead to significant findings for teaching reasoning skills to subjects in grade four and five. Bass and Perkins (1984) found that the educational software led to increased but not statistically significant skills in verbal analogies and inductive/deductive reasoning. There were no differences in logical reasoning and word-problem analysis. With kindergarten subjects, vonStein (1982) found no significant differences between the experimental and control groups in their ability to sequence shapes. Both groups gained in performance, albeit not significantly.

Summary: Findings on Teaching Higher-order Thinking Skills to Children and Adolescents

In summary, the research clearly shows that children and adolescents of varying ages can learn a variety of higher-order thinking skills. However, there is the caveat that

foundational knowledge can impact whether the subjects can learn the skills of the research interventions.

In general, to be able to solve logic problems, individuals need declarative and procedural knowledge. Declarative knowledge is the facts that individuals know, such as definitions. Procedural knowledge is the skills that one is able to do, such as basic arithmetic computations (Valanides, 1996). For this research, with the classification and analogical-reasoning skills, subjects needed to know the definitions of the words presented. With respect to the sequencing skills, subjects needed to be able to do basic arithmetic computations, such as adding, subtracting, multiplying, and dividing. Age-appropriate English language skills were needed for all of the skills taught. Basic computer literacy, such as how to use a mouse, was needed for the educational-software intervention. Beyond that, for all of the skills, the learner needed to be at the appropriate level of cognitive development to be able to learn each logical-thinking skill.

Specifically, based on Piaget's theory of cognitive development, Vygotsky's Zone of Proximal Development model, and the above studies, subjects in grade six and seven, who respectively were eleven and twelve years old, should be able to learn the classification, analogical-reasoning, sequencing, and deductive-reasoning skills from the educational-software and paper-based interventions of this research. No studies were found regarding teaching elementary-school children the patterning skill of this research.

2.2.2 Long-term and Short-term Memory

Information received from the environment through sensory receptors (from sight, sound, taste, smell, and touch) is converted to electrochemical messages that are sent to the brain. The human mind then decides what to do with the information. If the

information is deemed important, the information is moved from the sensory registers to the short-term memory (Fenrich, 2014; Heo, 2012).

Short-term memory can hold a limited amount of information for a short period of time. If the brain decides that the information is not important, the information fades away. Alternatively, if the brain determines that the information is important, the information can be manipulated and then processed for storage into long-term memory. This processing requires information to be passed from long-term memory into short-term memory so that the information can be encoded for later retrieval from long-term memory. Encoding integrates the new information with previous information that was already stored in long-term memory. This integration enables information to be stored in a way that is meaningful to the individual. Long-term memory is thought to have an unlimited capacity to store information for long periods or possibly a permanent amount of time. As is needed, information in long-term memory is moved to short-term memory when a person specifically thinks about it (Fenrich, 2014; Heo, 2012).

Integrating new information into long-term memory is done by an active process of assimilation or accommodation. Assimilation is used when the new information fits into an individual's existing mental model. Accommodation is used when the new information does not fit into an existing mental model. With accommodation an individual creates a new mental model that accounts for both the previously known information and the new information. For example, someone may have a mental model that all birds have feathers and can fly. If the individual learns about a new bird, such as a hawk, the learner assimilates the information about the hawk into his or her existing model of birds. If the individual learns about an ostrich, his or her existing mental model that all birds have feathers and can fly is inaccurate since ostriches cannot fly. Having a flawed mental model causes a dissonance. This dissonance usually leads

individuals to want to achieve a balance or an equilibrium. So to lessen the dissonance, the new information about an ostrich is accommodated through the individual creating a new mental model such as: all birds have feathers and most birds can fly. The new mental model enables the individual to achieve an equilibrium with his or her known information. However, there is no guarantee that the resulting mental model is accurate. For example, some penguin chicks have been born without feathers. If the individual learns of this fact, he or she must make another accommodation so that this new information fits into his or her mental model about birds. In general, instructional strategies must be designed to facilitate the assimilation or accommodation of new information in short-term memory to long-term memory so that the information can be easily retrieved from long-term memory (Fenrich, 2014; Katzlberger, 2006; Robertson, 2005).

Based on cognitive load theory, instructional strategies need to factor in the limits of short-term memory. If too much information is presented at one time or over a period of time, some learners will not be able to mentally process all of the information. If the learner cannot process all of the information, some important information may be missed. As Heo (2012) stated, “meaningful learning cannot occur when the processing channel is overloaded since people have a limited working memory” (p. 26). Strategies that can help to prevent the processing channel from becoming overloaded are to limit the amount of information that is presented concurrently, provide information in manageable chunks, and not present or limit the presentation of extraneous information (Fenrich, 2014; Heo, 2012; Reid, 2010). Avoiding or limiting the presentation of extraneous information is consistent with the coherence effect. According to Heo (2012), the coherence effect refers to findings that showed students learning more when irrelevant information was excluded from a presentation.

As mentioned above, instructional strategies must support the transfer of information into long-term memory and retrieval of information out of long-term memory. There are many techniques that can assist with that. For example, new information can be linked to information that a learner should already know (e.g., by stating similarities and differences), the information can be presented in a structured format (e.g., with tables or headings and sub-headings), questions can be asked and feedback can be given, and memory techniques (e.g., mnemonics) can be used (Fenrich, 2014; Heo, 2012; Katzlberger, 2006; Roberston, 2005).

2.2.3 Constructivism

Constructivism is a prevailing theory about how people can effectively learn. A constructivist approach can be a part of an instructional strategy. According to Katzlberger (2006),

People can memorize information that is meaningful and related to previous experience much easier than meaningless unrelated information. People merge new knowledge with what they already know (Tripathi 1979). This means that our memory does not simply recall facts, but can modify or even introduce new information. Thus, our memory is constructive (p. 15).

The constructivist theory states that humans should be exposed to learning events so that they can construct their knowledge, through assimilation and accommodation, based on their prior knowledge, beliefs, and experiences. The resulting interpretation of the experience and construction of knowledge is unique to the individual. The interpretation may or may not be accurate (Bradberry-Guest, 2011; Katzlberger, 2006; Lambert et al., 2002). So, one cannot assume that the learner will interpret material as intended. Each learner's construction may have changes, additions, or omissions. Instructional strategies must provide practice and feedback so that the learner has the opportunity to construct accurate interpretations of the content taught (Burkhart, 2006;

Cott, 1991; Fenrich, 2014; Katzlberger, 2006). Another constructivist approach is to let learners control their own learning (Ruzhitskaya, 2012). This is a basic tenet of self-paced materials. An advantage of a student working with self-paced materials, as compared to traditionally delivered materials, is that he or she can spend more time on content that he or she is having difficulties with (Cott, 1991; Fenrich, 2014).

There are numerous instructional strategies that can be applied when creating instructional materials. With respect to constructivism, Katzlberger (2006) stated,

Two pedagogical approaches that comply with the principles of constructivism are learning by doing and active learning. These strategies are based upon the idea that people learn best by doing things, not by being passive recipients of knowledge (Lander et al. 1995; Modell and Michael 1993). Some studies have found that higher order thinking skills are not acquired through didactic approaches, but rather through learner's active involvement with information (Collins, Brown, and Newman 1989) (p. 36).

Learning by doing, such as answering questions, and active learning lead to learners thinking and being engaged in the content, which results in learners constructing knowledge. This leads to greater and more efficient learning as compared to passive approaches (Cott, 1991; Larson, 2010; Ruzhitskaya, 2012; Stratton, 2003). Active learning has been a common instructional strategy within educational software and other self-paced materials (Cott, 1991).

2.2.4 Practice and Feedback

As mentioned above, questions and feedback support constructivist learning. Questions engage learners and feedback helps learners create an accurate mental model of the information. Katzlberger (2006) states that constructivist theories postulate that a wrong answer “causes a cognitive disequilibrium, which forms the basis for students to correct their erroneous understanding of concepts and procedures” (p. 20). Feedback can explain why an answer is correct, clarify why distractors are incorrect, provide

hints, give directions, ask learners to reflect, provide counterexamples, discuss misconceptions, or ask another question to guide the learner to the correct concept (Fenrich, 2014; Katzlberger, 2006). Feedback should be immediate, constructive, and clear (Cott, 1991; Fenrich, 2014; Katzlberger, 2006). Practice and feedback are strengths that instructional resources, including stand-alone educational-software and paper-based materials, can contain (Fenrich, 2014).

2.2.5 Metacognition

As discussed above, constructivist instructional strategies include a learner controlling his or her own learning. Metacognition, where an individual thinks about his or her own thinking, can help a learner control his or her own learning by enabling one to define a learning goal and monitor his or her progress in achieving that goal. A student can decide what to spend more time on, what to study next, and what actions can lead to increased success. It is commonly assumed that metacognition helps student performance and is thus recommended as a strategy that can be adopted into self-paced learning materials (Arslan & Akin, 2014; Bessick 2008; Burkhart, 2006; Katzlberger, 2006).

2.2.6 Motivation

Motivation is known to be a key factor in student success. Students tend to spend more effort and time on learning when they are motivated. Theorists describe both extrinsic and intrinsic motivation. Extrinsic motivators are rewards (e.g., a good mark), awards (e.g., a degree), and punishments. Intrinsic motivation stems from the joy of doing something. Intrinsic motivation can come from enjoyment of the activity itself (e.g., it is fun or challenging or the problem is interesting), personal pride, and a sense of accomplishment. Within learning materials, intrinsic motivation can be fostered, for

example through praise, stimulating curiosity, comments about effort, and statements about progress or how much has been learned. Proceeding at one's own pace can also be motivational (Cott, 1991; Fenrich, 2014; Katzlberger, 2006; Ruzhitskaya, 2012).

An added benefit of asking questions and providing feedback is that they maintain or help to maintain a learner's attention and seem to act as a powerful motivator in that humans can be highly curious about why they made a mistake (Cott, 1991; Katzlberger, 2006). As well, it is motivational to know that one has succeeded in learning content and this can stimulate further effort (Cott, 1991; Fenrich, 2014).

2.3 Instructional Design

The literature provides little with respect to how to design and develop instructional materials that teach higher-order thinking skills, and provides even less on the more specific logical-thinking skills. It is particularly important to have an effective design and development model to follow to create these materials because it is known that many teachers do not follow a specific model for creating instructional materials, although many incorporate components of instructional design and development models when designing content (Hart, 2008). According to Singh (2010), by using a model that gives a systematic approach to creating instructional materials, the process will be both empirical and replicable and, through measurement, it can be determined whether learning outcomes are being achieved, and, if not, the content can be revised. As a definition, "the instructional development cycle is the systematic repetitive process of activities you need to do to solve an instructional problem" (Fenrich, 2014, p. 52).

Design, or more specifically, instructional design is a major step in the instructional development cycle. Instructional design outlines "the ways to apply learning theory to create an effective lesson or unit (Morrison et al., 2001)" (Maryannakis, 2009, p. 49).

In general, to ensure effective learning, the instructional design of educational materials should be based on Gagné’s Nine Events of Instruction and a foundation of constructivist principles. Singh (2010) stated that Gagné’s Nine Events of Instruction method for designing materials is “still being used today by instructional technology researchers because it adds theoretical substance and value to their body of research in instructional design. It also offers a practical guideline to instructional designers” (p. 59). Through the analysis done in the instructional design process, an instructional strategy is created to teach each specific skill.

In this section, instructional development models, steps of instructional design, Gagné’s Nine Events of Instruction, how higher-order thinking skills can be taught, and instructional strategies for teaching analogies are discussed.

2.3.1 Instructional Development Cycle Models

Instructional development cycle models are used to guide the instructional development process to result in materials that promote learning, regardless of the delivery method (e.g., traditional, paper-based, and educational software). ADDIE is a foundational instructional development cycle model. ADDIE is an acronym for the phases of Analysis, Design, Development, Implementation, and Evaluation. Each phase consists of numerous steps and provides inputs for the next phase, as illustrated in Figure 2.3 (Dunning, 2008; Fenrich, 2014; Hart, 2008; Kingston, 2011; Parsons, 2008; Reddy, 2007; Singh, 2010).

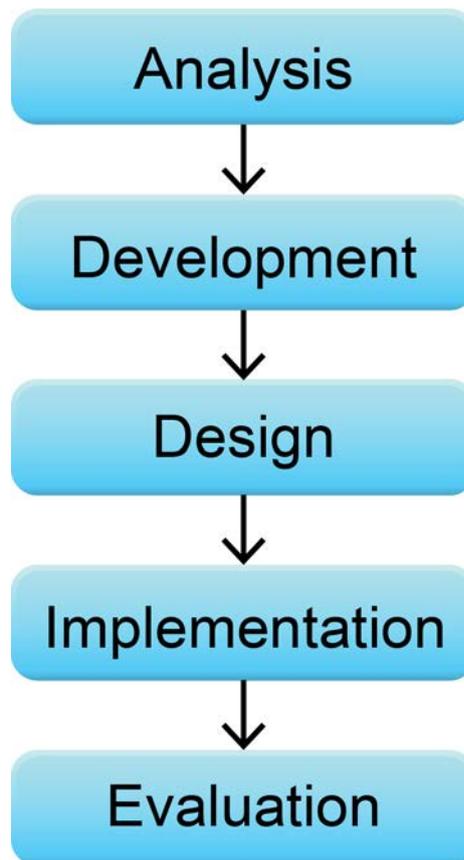


Figure 2.3 – ADDIE Model

There are over 100 models used to develop and design instructional materials and the generic ADDIE model is typically germane to these models (Parsons, 2008; Singh, 2010). In agreement, Kingston (2011) said,

The past few decades have seen a number of instructional design models emerge, though these models appear new and provide their own qualities, they seem to share more similarities than differences and can often be described as variations of the ADDIE process of instructional design (Prester, 2004) (p. 10).

Instructional development models enable instructional designers to visualize the entire process, establish guidelines, manage the process, and facilitate communication between team members (Singh, 2010). Reddy (2008) claimed that the ADDIE model allows for the flexibility needed to address a wide array of learning outcomes and is effective in helping to breakdown a complex process into manageable steps. However, some believe that ADDIE is not the panacea of instructional development models. Kingston (2011) stated that ADDIE is effective for designing instruction for well-

defined problems but is not ideal for ill-defined problems. As well, the ADDIE model can be restrictive, for example, if a linear approach is followed as shown in Figure 2.3. Parsons (2008) suggested that a “nonlinear approach is important to make it possible for continuous interaction between the evaluation or diagnosis and the instructional design recommendation (Tennyson, 1997)” (pp. 25-26). In support of the ADDIE model, Singh (2010) stated that following an instructional development model like ADDIE provides an advantage of supporting replication. This can work in some cases, however, replication can potentially lead to weak designs as there is no guarantee that the instructional strategy and process that worked for solving one instructional problem will work perfectly for the next instructional problem. For example, teaching someone to choose to not drink and drive is likely to be taught in an inherently different manner than teaching someone strategies for playing football.

Systematic process of instructional design

Simply following the ADDIE model, or a variation of it, does not in itself lead to effective instructional materials, as the instructional development models do not state the steps needed for designing instructional strategies. Within the instructional development cycle, a systematic process of instructional design must also be followed to ensure that instructional materials are educationally sound (Fenrich, 2014). The general steps for the instructional design of materials, as developed by Dick and Carey (1990), include identifying the instructional goals, conducting an instructional analysis, identifying entry behaviours and learner characteristics, writing performance objectives, developing criterion-referenced test items, developing an instructional strategy, developing and selecting instructional materials, designing and conducting formative evaluations, and designing and conducting summative evaluations. A variation of these steps are discussed below within a variation of a non-linear instructional development

cycle, which include the phases of analysis, planning, design, development, implementation, and evaluation and revision.

Analysis phase

At the start of the analysis phase, one should identify the instructional goal(s) and refine these into specific performance objectives or learning outcomes, while ensuring that the problem needs an instructional solution. The analysis phase should provide a concise problem definition.

The first step in the analysis phase is to identify the instructional goal(s). Instructional goals are general learning outcomes that can be broken down into precise skills that can be measured. Learning to speak conversational English is an example of an instructional goal. To identify the instructional goal(s), one should define the actual instructional problem. One can gather the information for defining the problem through a needs assessment. A needs assessment is a method for determining the actual problem, rather than the symptoms of a problem. For example, an individual may refuse to use the new computer software because the “software doesn’t work”. In this case, the symptom, refusing to use the software, may be hiding the real problem, which might be a fear of change.

After the instructional goals are identified, the next activity in the analysis phase is to conduct an instructional analysis, which includes a goal analysis and subordinate skills analysis. The purpose of a goal analysis is to create a general but precise visual statement of the consecutive steps that a learner will do to achieve the goal. The focus is on what learners need to do, rather than what learners need to know. Subsequent to the goal analysis, a subordinate skills analysis should be conducted. A subordinate skills analysis is done if the sequential steps derived in the goal analysis are too large to be taught in one step or to determine if the learners need more information prior to learning

a step. The end result may be that some or all of the steps are broken into smaller elements.

After the subordinate skill analysis, entry behaviours and learner characteristics should be identified. For effective learning, there must be a match between the instructional materials and the capabilities of the widest practical range of learners. The learners' abilities, language level, motivation, and interests should be considered. This information can be obtained by interviewing teachers and learners, reviewing existing documentation such as test scores, and/or testing learners. The resulting information determines the skills that, in general, the target audience has mastered before the intervention begins. These skills are not taught. This decision should be confirmed by asking the reviewers if the entry skills should be tested within the lesson. If the skills should be tested then the skills should be taught.

The final step with respect to instructional design in the analysis phase is to write performance objectives. Performance objectives form the basis of all of the subsequent steps. Performance objectives are specific measurable skills that describe what learners should be able to do. Performance objectives are more specific than instructional goals. For example, for a goal of speaking conversational English, a performance objective could be to conjugate the verb "to be". The instructional materials are effective when learners achieve the planned objectives. Accurate, well-written performance objectives can save time by helping to keep the process on track. To illustrate this, without well-written performance objectives, it is easy to provide interesting content that is not relevant. If there is doubt about whether content should be a part of the instructional materials, refer back to the stated performance objectives.

The last step in the analysis phase is to conduct formative evaluations and make revisions.

It is important to do everything in the analysis phase thoroughly. Quality work helps to prevent wasted effort in revisions in the subsequent phases (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

Planning phase

The planning phase helps the instructional development process proceed smoothly. In the planning phase, it is important to provide initial estimates of the resources needed, even though the estimates may be inaccurate until there is more information. The estimates can help to determine if there may be resource constraints. Another important part of the planning phase entails identifying and addressing potential problems. Other tasks include assembling the team and setting timelines.

As mentioned, one part of the planning phase is to identify and address potential problems. For example, there needs to be acceptance and commitment from all involved. Authorization may also be needed. Consideration should be given to potential financial issues, personnel availability issues, facility restraints, hardware limitations, and whether the prototype software will run on the anticipated delivery system.

In the planning phase one should start assembling the team. This can be done by specifying and assigning members to the team while taking into account how the project will affect workloads. Training may need to be provided if some of the needed skills are not held within the team's skill set.

In the planning phase, timelines can be set and resources needed throughout the instructional design and development process can be reserved. Generous timelines are recommended in case some tasks take longer than expected. The timelines must factor in some tasks being dependent on others being completed.

The last step in the planning phase is to conduct formative evaluations and make revisions.

By completing these tasks in advance, the design, development, and implementation phases should have fewer surprises and problems (Fenrich, 2014; Reddy, 2008).

Design phase

Based on the stated performance objectives of the analysis phase, the design phase leads to the creation of the instructional strategy for each learning outcome. The instructional strategy is what is designed to enable students to effectively and efficiently learn. In the design phase, the standards and look and feel are defined. Another step is to confirm all of the resource requirements.

An initial step in the design phase is to develop criterion-referenced test questions. This is done for each of the performance objectives. A part of this step is to determine whether the test actually measures what it is intended to measure. Being able to test a performance objective helps to confirm that the objective is written correctly. If a performance objective cannot be tested then revisions are needed. Note that this step and subsequent steps may entail the creation of content or other parts of the materials. Consequently, the design and development phases often overlap.

A challenging part of the design phase is to develop instructional strategies. Instructional strategies are needed for each of the performance objectives and are created by following principles of instructional design. This task is the crux of the instructional solution as flaws in instructional design will compromise learning. This can be particularly important with educational software (Fenrich, 2014). According to Mayrath (2009), “when used ineffectively, technology is distracting, frustrating, and can significantly decrease learning (Clark & Choi, 2005)” (p. 2). Within the instructional strategies, it is important to determine what media are needed to support learning.

Instructional design is discussed in detail below, particularly within Gagné's Nine Events of Instruction.

Within the design phase, standards should be determined. Decisions need to be made on the writing style and tone and, as is appropriate for an intervention (e.g., educational software or paper-based materials), set standards for menus, orientation information, headings, image locations, text locations, prompt locations, prompt wording, error messages, navigation text and/or buttons, branching details, fonts, font sizes, highlighting methods, colours, input devices, scoring for tests, and criteria for passing. Many of the standards listed relate to both screen and page design. Screen and page design are discussed below.

For an educational-software intervention, programming the above standards into templates and sub-routines can begin. If templates and sub-routines are created, a change made in a template or sub-routine is automatically applied whenever that template or sub-routine is used. This helps to ensure that the screen design and user-interface are consistent throughout the materials.

Another step in the design phase is to confirm or refine information regarding the needed resources, including personnel, equipment, and software, based on what is now known about the design.

The last step in the design phase is to conduct formative evaluations and make revisions (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

Development phase

The development phase entails creating and selecting the instructional materials and evaluating the materials.

The first step of the development phase is to develop and select the instructional materials, including the needed media, based on the instructional strategies and all of

the design specifications. If the instructional materials are to be paper-based, the core part of the work is essentially done after this step is completed. If the instructional materials are delivered in a different way, such as with educational software, the paper-based content is used as the foundation for developing those materials. However, thorough evaluation and revision of the paper-based content needs to be done before the materials are developed for a different delivery method as it is easier to make edits on paper than in other ways, such as within an educational-software authoring tool.

A critical step of the development phase is to conduct formative evaluations and make revisions. This should first be done with a prototype, which may be based on the materials for one performance objective or a small number of performance objectives. This is important as prototypes may work better in theory than in practice. Changes made in the prototype can be applied, as is appropriate, to all future content; thereby reducing the number of future revisions needed. During this step, observe the learners and ask clarifying questions if a learner struggles with any of the content or is unsure as to how to proceed through the material (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

Implementation phase

Implementation entails the step of trying the materials in a real setting to determine what works and what needs to change.

In the implementation phase ensure that the personnel, facilities, equipment (as needed), and instructional materials are available when scheduled. For educational software, the software should be run on the equipment that will be used for the full implementation. A team member should work through every screen and question answer choice. If needed, problems should be addressed.

Once everything is set up, based on a representative sample of target audience learners, conduct an evaluation and make revisions. Like the other phases, evaluation and revision are integral components of implementation.

After the instructional materials are thoroughly evaluated and revised, full implementation can begin (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

Evaluation and revision phase

Evaluation is the systematic collection and analysis of information to support decision making and planning. Formative evaluation should be ongoing throughout each phase of the instructional design and development process. Typically, educational software should be tested on different computer systems with varying speeds, memory, screen resolutions, and monitors. This should be done early in the process with initial prototypes. Revisions should be based on the feedback and data obtained in each iteration of evaluation. Since evaluation is ongoing throughout the instructional design and development process, revisions are also ongoing. Summative evaluation should occur after the instructional solution is fully implemented (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

2.3.2 Gagné's Nine Events of Instruction

To help ensure effective learning, the creation of educational materials should, in general, be based on principles of instructional design and follow a model such as Gagné's Nine Events of Instruction. Gagné's Nine Events of Instruction are gaining attention, informing the learner of the learning outcome, stimulating recall of prerequisites, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and

transfer (Al-Hadlaq, 1994; Gagné et al., 1988; Maryannakis, 2009; Parsons, 2008; Singh, 2010).

Gaining attention

The learners' attention should be gained to get the learners involved and motivated. As well, a learner's attention should be maintained throughout the learning materials (Al-Hadlaq, 1994; Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009; Singh, 2010). According to Fenrich (2014), some of the techniques that can be used to gain and maintain a learner's attention include showing or stating something interesting, making the materials highly interactive, asking questions, especially those that require deep thinking, providing a variety of learning activities, challenging the learner, and stressing the importance of the materials.

Informing the learner of the learning outcome

Informing learners of the learning outcome or performance objective enables them to focus their efforts (Al-Hadlaq, 1994; Fenrich, 2014; Singh, 2010). This can be done effectively with text (Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009).

Stimulating recall of prerequisites

By stimulating the recall of prerequisites, instructional designers can help students prepare for their learning experience (Fenrich, 2014; Gagné et al., 1988; Rosenshine, 2012; Singh, 2010). For many skills, foundational knowledge is needed for learning higher-level thinking skills (Fenrich, 2014; Miller, 2003).

Presenting the material

There are many principles for effectively presenting learning materials. The total amount of material presented in a lesson should be based on the learners' age, the

learner's expected attention span, the material's complexity, the activities needed to teach the skills effectively, and the time needed for all of the instructional events. In general, material should be presented in increasing difficulty and in small incremental steps. This helps ensure learner success and increases the learner's confidence (Fenrich, 2014; Gagné, et al., 1988; Rosenshine, 2012). Providing a variety of instructional strategies and activities can generate interest. The activities provided must support the learning outcomes being taught (Fenrich, 2014; Semper Scott, 2005; Solomon, 2008). As is warranted, a learner should actively participate in his or her learning (Baumer, 2009; Fenrich, 2014; Gagné et al., 1988). Learning by doing is very powerful. This was stated well by Guatama Buddha who said, "Teach you? I cannot teach you. Go, experience for yourself." Learning by doing becomes particularly important for instructional materials that require extensive reading since learners, due to the limitations of memory, cannot remember all that they read (Wu, 2009). Consequently, the instructional strategy must direct the learner's focus to the deeper learning concepts that support higher-order thinking skills (Wu, 2009). The learner can be directed to focus on deeper learning by making the material interactive through activities that require higher-order thinking (Enniss, 2006; Fenrich, 2014).

Providing learning guidance

Providing learning guidance is used to help students learn the material, such that the content is stored into long-term memory in a meaningful way that allows the student to retrieve the content from long-term memory (Fenrich, 2014; Gagné et al., 1988; Rosenshine, 2012; Singh, 2010). Learning guidance is often integrated with "presenting the material". As well, this event is typically combined with the "Eliciting the performance" and "Providing feedback" events (Fenrich, 2014).

Eliciting the performance and Providing feedback

The purpose of eliciting the performance and providing feedback is that learners must find out how well they are doing and how they can improve their performance. This can be done by asking questions or providing opportunities to practice the skill and then giving elaborative feedback. The questions asked should be at the highest appropriate thinking level to promote that level of skill development and should be asked throughout the learning rather than massed together, such as at the end of the instructional materials. Eliciting the performance and providing elaborative feedback are typically integrated together so that students can immediately see and understand consequences of their actions (Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009; Rosenshine, 2012). Answering questions is often an important part of an instructional strategy as it is more effective than being told information (Baumer, 2009). When teaching higher-order thinking skills, it is particularly important to provide practice and feedback (Bowman, 2000; Burkhart, 2006; Miller, 2003), as most students do not fully learn the skills without practice and feedback (Mains, 1997).

Assessing performance

Learners are formally tested in the assessing performance event. This step is more formal than eliciting the performance. All learning outcomes and only the learning outcomes should be tested. Test performance should be based on achieving the specified learning outcomes (i.e., criterion-referenced) as opposed to comparing students to each other (i.e., normative-referenced) (Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009; Singh, 2010).

Enhancing retention and transfer

In the enhancing retention and transfer event, students should be supported in retaining the information and transferring the skills beyond the specific ideas presented in the learning materials. Retention increases as exposure increases. Retention can also be supported through providing summaries. Retention activities should occur at spaced intervals and occur before more complex skills are learned. Transfer should be deliberately addressed to make transfer more likely to occur. Transfer can be facilitated by providing real-life, novel, and/or varied problems and solutions. As well, transfer is more likely as the amount of practice and feedback increases and if the skills measured are of the near transfer type (Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009; Meyer, 2010).

Summary: Gagné's Nine Events of Instruction

Gagné's Nine Events of Instruction are gaining attention, informing the learner of the learning outcome, stimulating recall of prerequisites, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer. Learning should occur if an instructional intervention includes these events, is based on principles of instructional design, and follows constructivist principles.

2.3.3 Designing Learning for Higher-order Thinking

Cott (1991) stated, "There is no reason that a well-developed PI system cannot teach underlying principles of a particular subject" (p. 7), where PI is programmed instruction. Similarly, Heo (2012) stated that if an intervention is based on an effective instructional method, there should be gains in learning.

The effectiveness of instructional materials is limited by the instructional design (Craig, 2007; El-Sanhurry, 1990; Maryannakis, 2009; Solomon, 2008). To ensure instructional effectiveness, educational software, paper-based content, and other instructional materials need to be designed based on principles of instructional design that are grounded on learning theory. The instructional design process should ensure many things including that the content is targeted to the intended audience, learning outcomes are stated, measurable, and at the highest appropriate level, learners are motivated to learn, the instructional strategies are designed to solve the specific instructional problem, and the materials are highly interactive (Fenrich, 2014; Gagné et al., 1988; Rosenshine, 2012; Solomon, 2008; Wu, 2009). Given that higher-order thinking skills are complex and challenging to teach, focussing on the instructional design of the materials is paramount. If this is not done, learning gains may be insignificant.

General Methods for Designing Learning for Higher-order Thinking Skills

Higher-order thinking skills need to be specifically taught in that learners do not tend to acquire these skills passively (Burkhart, 2006; Lee, 2008; Loiacono, 2000; Wruck, 2010). For example, in D'Antoni's (2009) study, which compared medical students who took notes through either the "normal" way or through a mind-mapping way, there were no significant differences in critical thinking between pre-test and post-test scores among the groups or between the groups, as assessed by the Health Sciences Reasoning Test. Given that taking notes either in the traditional way or through mind-mapping does not in itself lead to critical thinking, the lack of any differences supports the notion that higher-order thinking skills must be explicitly taught for a gain in higher-order thinking skills to occur. Cotton (1991), in her review of research studies where thinking skills were explicitly taught, found that each intervention resulted in improved

performance. However, explicitly teaching the skills is not a simple matter. According to Sondel (2009), “There is a dearth of information which evaluates the best ways to improve critical thinking” (p. 15). This is similar to Burhart (2006) who stated, “Largely absent from the literature is a means by which critical thinking instruction can be implemented” (p. 41).

Beyond having limited information on how to teach higher-order thinking skills (Thomson, 2009), there is a challenge in teaching higher-order thinking skills because these skills tend to be abstract and, as noted earlier, there is no agreement on how to define higher-order thinking skills (Jeremiah, 2012; Svenningsen, 2009; Wilson-Robbins, 2006). In other words, how do you teach and assess something if you are not sure what it is? Research findings are typically hard to generalize for a number of reasons but a particular difficulty arises because the construct used to define thinking varies dramatically between studies (Stambaugh, 2007). There is a further problem in that there does not seem to be one “right” method for teaching higher-order thinking skills in traditional teaching situations (Bessick, 2008, Clark, 2005; Miller, 2003), let alone for specific delivery methods or for specific higher-order thinking skills, such as each type of logical-thinking skill. This notion was supported by Cotton (1991) who stated, “Various instructional approaches enhance thinking skills” (p. 5). This is consistent with Toth (1996) who said that it may be advantageous to use more than one instructional method.

The instructional strategies to be designed should be based on the specific learning outcomes that need to be taught as well as the thinking processes that the learner needs to invoke to achieve the learning outcomes (Rukavina, 2003). In other words, if a student needs to learn facts, incorporating memory techniques could be a part of the instructional strategy. If a student needs to solve problems, a variety of

different techniques should be used, such as the teacher modelling his or her thinking processes while solving a sample problem, students discussing strategies with other students, and/or students reflecting on whether a strategy was successful. One common theme from the literature is that the instructional strategy or strategies needed for teaching higher-order thinking skills must focus on higher-order thinking skills. One reason for this is that students often only superficially interact with typical instructional materials, which suggests a lower thinking level is being used (Enniss 2006).

To teach higher-order thinking skills, an instructional strategy can be based on the higher-order thinking skills in Bloom's taxonomy (Bloom et al., 1956), such as analysis, synthesis, and evaluation (Bradberry-Guest, 2011; Petris, 2009; Phillips, 1992; Svenningsen, 2009). As well, logical thinking can be enhanced through engaging students in problem-solving activities (Astleitner, 2002; Clark, 2005; Fenrich, 2002; Reid, 2010), incorporating case studies (Huff, 1998; Terry, 2007), teaching specific strategies that can be used as generic tools, especially if the thinking skills should be transferred to other situations (Belmont, 1991; Hurte, 2004), providing activities involving reasoning skills (Wellman, 1997; Vowels, 2008), role playing (Toth, 1996), having students provide reasons to support answers and viewpoints (Hugo, 1989), teaching argumentation (Carwie, 2010; Wu, 2009), asking higher-order thinking questions (Bradberry-Guest, 2011; Petris, 2009; Rigmaiden, 2011; Stambaugh, 2007), incorporating a discovery-learning approach (vonStein, 1982), using an inquiry-based strategy (Halsted, 1998; Huff, 1998; Jensen, 2008; Wilson-Robbins, 2006), generating and testing hypotheses (Reid, 2010), having students evaluate the inferences and/or assumptions they make (Elder & Paul, 2002; Paul & Elder, 2006; Shin, 2002), evaluating evidence (Scher, 1999), teaching the logic of analogical reasoning (Belmont, 1991; Huff-Benkoski, 1998; King, 2009; Vowels, 2008), applying metacognition

(Burkhart, 2006; Enniss, 2006; Wilson, 1986), discussing ideas (Huff, 1998; Lee, 2008), exploring alternative answers (Hugo, 1989), and teaching reading comprehension skills (Commeyras, 1991; King, 2009). Higher-order thinking skills can be explicitly taught through modelling (Belmont, 1991; Huff, 1998; Jay & Perkins, 1992; Wilson-Robbins, 2006). In general, as a part of an instructional strategy for teaching higher-order thinking skills, researchers suggest that enabling reflection, such as helping students reflect upon and understand the basic elements of the logic they are using or reflecting upon their work, facilitates the learning of higher-order thinking skills (Byland, 2005; D'Antoni, 2009; Halsted, 1998; Hughes, 2009; Martineau-Gilliam, 2007; Paul & Elder, 1999b; Vowels, 2008). Specifically, Byland (2005) suggested that instructional strategies should include appropriate examples and encourage self-reflection as ways to support learning critical-thinking skills. In a qualitative study of teaching by traditional methodologies with post-secondary subjects, Allrich (2002) found that reflective thinking was important for achieving higher-order thinking skills. Chang's (2002) research showed that critical thinking can be promoted in an online environment when there is constructivist instructional design, reflective learning strategies, collaborative activities, and the opportunity to engage in multiple perspectives. However, Chang did not determine whether any activity on its own would lead to gains in critical thinking. Bullen (1997) determined that reflective thinking was a factor in gaining critical-thinking skills, when learning through computer conferencing in a post-secondary setting. Andrusyszyn's (1996) research suggests that reflective thinking, such as self-evaluations, should be actively encouraged to increase critical-thinking skills. Her research involved subjects who were mainly in graduate studies that were taught through computer conferencing. The above methods can be integrated with other

strategies, such as cooperative learning, which has helped increase critical-thinking ability (Asamani, 1998).

Teaching higher-order thinking skills requires planning, such as gradually building the skills in incremental steps to help ensure success (Bessick, 2008; Reid, 2010), disciplined practice that ideally becomes integrated into a learner's daily activities by habitually assessing his or her work based on standards of logical thinking, such as checking one's assumptions (Hurte, 2004; Paul & Elder, 1999a), and intense practice (Burkhart, 2006) as these skills require significant effort to learn. In contrast, the stereotypic didactic instructional approach and traditional drill-and-practice have been shown to be relatively ineffective in teaching higher-order thinking skills (Almatrodi, 2007).

An ongoing debate has been whether it is better to teach higher-order thinking skills in a course dedicated to teaching generic higher-order thinking skills, in an integrated approach within a number of courses, or both within a dedicated course and within other courses (Almatrodi, 2007; Enniss, 2006; Sondel, 2009). Research has shown that significant gains in thinking skills can be attained by teaching thinking skills via each of these approaches (Bessick, 2008; Burkhart, 2006; Commeyras, 1991). Some researchers advocated teaching higher-order thinking skills both within a dedicated course and within other courses to gain the advantages of each method and reduce the risks of each method (Burkhart, 2006; Commeyras, 1991; Semper Scott, 2005). Courses dedicated to teaching higher-order thinking skills were more likely to provide the concentrated time and effort needed to learn and practice the skills and develop a clear understanding of the skills as compared to an integrated approach (McCormick, 1988; Semper Scott, 2005). As well, dedicated courses do not have the same risk of having the content of the course override the importance of higher-order thinking skills (Semper

Scott, 2005). Another potential advantage of having a course dedicated to teaching higher-order thinking skills is that the learning outcomes are more likely to be accurately assessed (Semper Scott, 2005). Transferring higher-order thinking skills to novel situations is an important goal of teaching these skills (Abrami, 2008; Reid, 2010; Solomon, 2008; Young & Maxwell, 2007), regardless of whether the skills are taught within the curriculum or independently. Floyd (1992) suggested that teaching generic thinking skills may be a better method for helping learners transfer the concepts to new situations when there is a distinct effort to build connections. However, other researchers are concerned that the generic approach will not ensure a transfer of skills to where the skills are needed (McCormick, 1988; Miller, 2003; Semper Scott, 2005). It has been questioned whether generic courses address all of the specific higher-order thinking skills that are needed in a discipline of study (Christian, 1995), especially since higher-order thinking skills should be a part of every discipline of study (Hugo, 1989). For example, it would not be expected that a generic course on higher-order thinking skills would thoroughly teach every diverse skill, such as how to write literary criticism, diagnose diseases accurately, find flaws in arguments, and use logic to write computer programming code or solve math equations. Others support teaching higher-order thinking skills in every course as this would diminish the risk of students not being able to transfer the thinking skills and would help develop the student's understanding that thinking skills should be applied in all areas of life (Semper Scott, 2005). As well, teaching higher-order thinking skills within "regular" courses would show where the thinking skills are relevant in the courses (Thomson, 2009). Given the arguments, using both a dedicated course and integrated approach within a number of courses would address the weaknesses of each alternative (Miller, 2003). Perhaps, convenience based on logistical reasons, such as school support and the time needed by teachers and

students, should be why one approach is chosen over another. Given that higher-order thinking skills need to be applied throughout one's life, encouraging and supporting a disposition to thinking critically and logically is needed for long-term success (King, 2008; Legant, 2010; Sondel, 2009; Thomson, 2009).

It is clear that there is no single way to teach higher-order thinking skills (Floyd, 1992). One reason that there is no single way to teach higher-order thinking skills is because many of the higher-order thinking skills are inherently different. Consequently, it makes sense that different skills could or should be taught differently. For example, different instructional strategies and activities would be needed to effectively teach the logic of analogical reasoning as compared to teaching argumentation. In contrast, some instructional strategies would be difficult to use to effectively teach some higher-order thinking concepts. As an example, using case studies to teach numerical-sequencing skills would be challenging and could potentially compromise learning. It is, however, important to note that some techniques could be effective for teaching a variety of higher-order thinking skills. For example, these techniques include focusing on higher-order thinking skills, modeling, asking questions that are at a higher-order thinking skill level, providing feedback, gradually building the skills, and self-reflection.

Summary: Designing Learning for Higher-order Thinking

In general, if an instructional intervention explicitly teaches and focusses on higher-order thinking skills and the intervention is designed well, significant gains in higher-order thinking skills would be expected. Although there is no single way to teach higher-order thinking skills, effective designs can or should include a variety of instructional strategies, specifically address each learning outcome, gradually build the skills, incorporate a constructivist approach, provide extensive practice, give elaborative feedback, encourage metacognition, and motivate the learners. With respect to this

research, if the design is effective, it would be expected that there would be significant gains in higher-order thinking skills.

2.3.4 Instructional Strategies for Teaching Analogies

For subjects in grade six and seven and the specific logical-thinking skills addressed within the interventions of this study, the literature only provided ideas for teaching analogical-reasoning skills. Masteron and Perrey's (1999) instructional strategy entailed learners determining a relationship between the first pair of words, pairing the third word with a word in the list that has a relationship like the relationship between the first pair of words, and creating a sentence that incorporated those relationships. Masteron and Perrey presented sample analogies, had the subjects practice analogies in groups, and then had the subjects practice individually. Judy (1987) and Wilson (1986) used an instructional strategy that was similar to Masteron and Perrey, with the main difference being that the subjects were not encouraged to create a sentence about the relationships. Johnson (1997) had subjects read a metaphorical story that detailed how analogies can be solved and how the skill can transfer, and had a training session for each of the three types of analogies taught. The story and training sessions entailed reading, discussions, practice exercises, group work, and individual work. Johnson's instructional strategy involved learners recognizing that the pairs of terms were equivalent but not identical, determining a relationship between the first pair of words, and pairing the third word with a word in the list that has a relationship like the relationship between the first pair of words.

2.4 Transfer of Learning

Given near transfer refers to when the skill learned transfers to situations that closely parallel what was taught and far transfer occurs when the skill learned transfers

to situations that are distinctly different from what was taught (Meyer, 2010), it is expected that learning gains are more likely if the skills measured are of the near transfer type (Grossen, 1988; Maryannakis, 2009; Meyer, 2010). Similarly, Lafferty (1996) noted that learning gains are more readily achieved with near-transfer skills but also stated that modeling may not be enough to elicit a gain in far-transfer skills, and an increase in the ability to transfer skills requires a deliberate effort, particularly for far-transfer skills. Hurte (2004) suggested that the far transfer of higher-order thinking skills is facilitated when individuals can apply the skills in their professional or personal lives while Rocks (2004) stated that transferring higher-order thinking skills is enhanced when a learner has developed a deep level of connected learning with respect to those skills.

Consequently, one cannot assume that there will be a transfer of skills, even when near transfer is emphasized and measured. Katzlberger (2006) stated, “Knowledge learned by a student may be associated with a specific context and stay inert in other problem settings” (p. 17), where “inert knowledge implies that a student is unable to transfer knowledge to a new domain” (p. 17). Larson (2010) contended that a failure to transfer skills to new situations can likely be attributed to weaknesses in the instructional strategies of the intervention. Designing instructional strategies to facilitate the transfer of learning is problematic because there “are few definitive guidelines that constitute appropriate designs” (Larson, 2010, p. 39).

As a general principle for instructional design, Christian (1995) suggested that the transfer of higher-order thinking skills will only occur if an instructional intervention is specifically designed to facilitate the transfer of skills. Another general guideline for facilitating the transfer of skills is that the practice and feedback of the

skills is needed in different situations (Bessick, 2008; Hurte, 2004; Lafferty, 1996; Larson, 2010). This was succinctly stated by Bessick (2008),

Students must learn to develop cues to retrieve information to prepare them for the demands of critical thinking. To do so, students must have ample opportunities to practice these skills under variable conditions to achieve better learning (Halpern et al., 2003) (p. 48).

Summary: Facilitating the Transfer of Learning

Learning gains were more likely to occur when there was a deliberate effort to teach near-transfer skills, especially when a learner was able to connect deeply with the skill. However, a number of interventions were unsuccessful in transferring higher-order thinking skills, possibly due to weaknesses in the instructional strategies of the intervention. One problem was that there were no definite ways to design materials so that the transfer of learning was assured. However, some basic strategies, such as providing practice opportunities of the skills in different situations, were recommended. Given that some potentially effective principles were implemented in the interventions of this research, gains in the ability to transfer logical-thinking skills were expected.

2.5 Screen and Interface Design

The screen or page design can impact the success of educational software and paper-based materials. Both educational software and paper-based materials need to be intuitive to use, such as with how to proceed, not becoming lost, and being able to review as needed. As well, both educational software and paper-based materials need to be written in language that is appropriate for the learner with the text being clear and concise. Software needs to be visually appealing and intuitive to use (Fenrich, 2014; Solomon, 2008). For many learners, the preferred writing style is conversational due to the personalization effect. Heo (2012) stated, “The personalization effect is that students

learn more deeply from a multimedia explanation when words are presented in a conversational style rather than in a formal style (Mayer, 2005)” (p. 29).

According to Fenrich (2014) and Solomon (2008), both educational software and paper-based materials should be visually appealing, such as through having “white space” so that the screen or page does not feel crowded, minimal changes in fonts to help give a professional appearance, consistent font sizes for the different screen or page components to help prevent confusion, consistent placement of items such as orientation information, instructions, text content, images, and feedback, and consistent use of colours. However, due to cost constraints, paper-based materials that are to be photocopied are often printed in black and white.

These principles of screen and page design were implemented into the interventions of this research. Consequently, the screen and page design were not expected to have any negative impact.

2.6 Assessment of Thinking Skills

According to Mackenburg-Mohn (2006), Rothman (2000), Belmont (1991), and El-Sanhurry (1990), there are a number of commonly used assessment instruments for measuring higher-order thinking skills. The suitability of each of these instruments for this research is discussed below.

The California Critical Thinking Skills Test assesses skills in analysis, evaluation, inference, inductive-reasoning, and deductive-reasoning. The test is designed for college-aged participants and professional adults and was therefore inappropriate for this study. Researchers have critically commented that the instrument emphasizes verbal skills and the tool has low internal consistency and poor construct validity (Burkhart, 2006).

The Cognitive Abilities Test measures ability in classification, analogical reasoning, sentence completion, quantitative relations, sequencing, equation building, figure classification, and figure analogies. The analogical-reasoning skills are similar to those of this study. The sequencing skill is assessed at a much simpler level than what is covered in the interventions of this study. The classification skill is based on figures rather than the text used in this research. The patterning and deductive-reasoning skills of this study are not assessed by the instrument. In general, the instrument is designed for students in grades two through five, rather than the grade six and seven subjects of this study. Due to the numerous differences, this tool did not fit the needs of this research.

The Cornell Critical Thinking Test measures assumptions, induction, deduction, observation, value judgment, credibility, and meaning. According to McCormick (1988), this test “has a high reading level, lacks a taxonomy of skills, and has not been shown to be valid or stable over time” (p. 87). Since, the instrument focuses on what one should do and believe rather than skills addressed in the interventions, this test was unsuitable for this study.

The Ennis-Weir Critical Thinking Essay Test uses letter writing or essays as the medium to measure an individual’s ability to evaluate a given argument that is based on real-life problems. It fits well with Socratic and didactic approaches to teaching. The skills taught in this study are fundamentally different and it would have been erroneous to assess the learning outcomes of this study via letter writing or essays.

The Halpern Critical Thinking Assessment Using Everyday Situations assesses critical thinking. It has an advantage over some tools in that the instrument uses both open-ended and closed-ended questions, which have been shown to measure different cognitive abilities (Burkhart, 2006). However, the tool is designed for secondary and

post-secondary students and also measures different skills than this research. The skills it measures include verbal reasoning, argument analysis, hypothesis testing, decision making, and problem solving. Consequently, the instrument was not appropriate for this research.

The Metropolitan Achievement Test assesses science achievement, critical thinking, and language development. This tool does not match the specific skills addressed in this research.

The New Jersey Test of Reasoning Skills assesses, through multiple-choice questions, critical-thinking skills in grades four through to college students, making the test age appropriate for this study. However, the test assesses different skills than those of this research, such as syllogistic reasoning and identifying assumptions, and was consequently not useful for this research.

The Otis-Lennon School Ability Test is used for assessing individuals from pre-kindergarten to age eighteen. It measures verbal comprehension, verbal reasoning, figural reasoning, and quantitative reasoning.

Verbal comprehension questions include antonyms, sentence completion, and sentence arrangement. This research did not address any of those skills.

Verbal reasoning questions entail logical selection, verbal analogy, and verbal classification, of which the latter two are addressed in this study. However, these questions also include arithmetic reasoning, word/letter matrices, and inference items that were not covered in this research.

Figural reasoning questions involve figural series questions, which relate to but do not match the patterning skill in this study, as well as figural analogies and pattern matrices, which were not addressed in this research.

Quantitative reasoning items include number series, numeric inferences, and number matrices. The latter two items were not addressed in this study.

Due to the large number of test items that address skills not covered in this research, the number of test items that only partially relate to the skills taught in this research, and that deductive reasoning would not be tested at all, the Otis-Lennon School Ability Test was not an appropriate instrument for this research. A further problem for this and other assessment tools was that selecting a subset of questions can affect the tool's reliability and validity (Reed, 1999).

The Ross Test of Higher Cognitive Processes is aimed at grades four to six students as opposed to the grade six and seven students of this study. It consists of multiple choice questions that assess skills such as analogical reasoning, deductive reasoning, verbal reasoning, word relationships, assumption identification, analyzing whether information is relevant and sufficient for mathematical problems, analyzing attributes of complex stick figures, and sentence sequencing. Although the skills of analogical reasoning and deductive reasoning could have been applicable to this study, the other skills of the intervention, classification, sequencing numbers, and patterning, are not assessed by the instrument. Consequently, the tool was not appropriate for this study.

The Stanford Achievement Test contains a critical-thinking subsection that measures a learner's ability to analyse and synthesise information, evaluate information to determine cause and effect, draw conclusions, make inferences, differentiate between fact and opinion, identify irrelevant information, and hypothesise. The Stanford Achievement Test cannot be administered more than once in six months. Thus, the test was not used for this study due to this study's shorter duration and the different skills

that would be assessed. The Stanford Achievement Test has been criticized for its emphasis on verbal intelligence (Burkhart, 2006).

The Test of Logical Thinking or Group Assessment of Logical Thinking tool specifically addresses skills regarding correlation reasoning, proportional reasoning, probabilistic reasoning, combinatorial reasoning, controlling variables, and conservation. In contrast to this study, many of the skills are applied in the context of mathematics and physics. In general, the tool focuses on a number of skills not addressed in the interventions of this study. Consequently, this tool would not have adequately measured the skills addressed in this research.

The Watson-Glaser Critical Thinking Appraisal instrument is a commonly used tool that assesses critical-thinking skills (Burkhart, 2006; Enniss, 2006; Shin, 2002). The instrument consists of true/false, multiple choice, and short answer questions that consider attitudes, knowledge, and skills. Specifically, the instrument assesses an individual's ability to define a problem, determine the information needed to solve the problem, identify assumptions contained in the problem, create and evaluate appropriate hypotheses related to the problem, and assess the inferences and conclusions made. The instrument includes questions relating to scientific facts and the weather as well as controversial topics such as social issues, politics, and economics, with some of the questions being particularly relevant to the United States of America. This instrument is designed for grade nine and older subjects. Due to the different skills it would assess and that it is designed for older subjects than those of this study, the instrument was inappropriate for this research. The tool has been criticized for correlating strongly with tests of reading competency (Burkhart, 2006) and only has adequate reliability (McCormick, 1988).

A compounding problem is that most commercial tests are norm-referenced (Gammill, 2000), where students are compared to each other. In a norm-referenced test, some students could score poorly even if they have a foundational understanding of the concepts. In contrast, in a criterion-referenced test, students are assessed based on their mastery of a concept. This research required criterion-referenced testing to accurately measure gains in logical-thinking ability.

Through pre-test and post-test scores of higher-order thinking skills on instruments such as those listed above, it has been shown that higher-order thinking skills can be quantitatively measured and students can gain in those skills through instructional interventions, given the caveat that increases in test scores indicate improvement in performance on the assessment tool and that is not necessarily proof that there is an increase in the higher-order thinking skills taught in the intervention (Semper Scott, 2005).

In conclusion, the instruments commonly used to measure higher-order thinking skills would not inherently measure all of the specific logical-thinking skills addressed in this research and not in the same context for the same age group. Consequently, none of these instruments were appropriate for this study. This was in agreement with Lee (2008), McCormick (1988), and Wilson-Robbins (2006), who stated that existing testing instruments tend to be too general to be useful and with Bessick (2008) who said that “there is no comprehensive test that assesses all aspects of critical thinking” (p. 50), and thus for logical-thinking skills or the specific skills of the construct for this study. In addition, Commeyras (1991) and Terry (2007), stated that there were few tests from which to choose and the existing tests assess specific thinking skills that do not necessarily reflect the content that is taught in an intervention. Similarly, Mains (1997) stated, “Studies have indicated that some tests have not actually measured cognitive

gains in the domains in which students were learning (Tobin & Capie, 1981; Ahlawat & Billeh, 1987)” (p. 46). Some assessment instruments containing multiple-choice questions were criticized because multiple-choice questions inherently limit a student’s thinking (Commeyras, 1991; Reed 1999; Sondel, 2009). In further support against using the assessment instruments described above, Almatrodi (2007), Hurte (2004) and Reed (1999) said that since there is no fully accepted definition of critical thinking, there is a large variability in how the construct is measured. In a similar vein, Lee (2008) stated that the tests vary with respect to the audience, their comprehensiveness, and the type of response required (e.g., essay and multiple choice). Lee also stated, in agreement with Almatrodi (2007) and Sondel (2009), that multiple-choice tests have limitations in that they are weak at recognizing attributes such as an individual’s open-mindedness or how the individual solved a problem. However, multiple-choice questions that are constructed well can reliably measure a number of higher-order thinking skills (Semper Scott, 2005). Although essays address some of the weaknesses of multiple-choice questions, essays cannot measure all of the higher-order thinking skills and can be problematic due to the subjectivity in their assessment (Almatrodi, 2007). Therefore, assessment needs to be based on the design of the intervention. This is in agreement with McDonald (2003) who stated that “the way critical thinking skills are taught should influence the way they are measured” (p. 16) and Roop (1996) who said that accurate measurement of higher-order thinking skills depends on how one defines the construct.

2.7 Findings on Teaching Higher-Order Thinking Skills

The findings of research on teaching higher-order thinking skills through educational-software are first presented and then studies entailing paper-based interventions are discussed.

2.7.1 Educational Software

The research on teaching higher-order thinking skills through an educational-software intervention has shown positive findings, mixed findings, and no significant differences. Research leading to positive and mixed findings are presented first.

Significant Findings through Educational Software

The studies discussed below show that learning through educational software can increase a learner's higher-order thinking skills, although some of the studies had mixed findings.

With post-secondary subjects taking an astronomy course, Ruzhitskaya (2012) quantitatively compared experimental subjects learning how to apply the stellar parallax concept through the Stellar Parallax Interactive Restricted and Unrestricted Tutorial educational-software program to control subjects who learned the concept through lectures and paper-based materials. The educational-software materials followed an inquiry-based approach that incorporated interactivity and visualizations that led subjects to construct knowledge based on making predictions, observing, reflecting, collecting data, and making calculations. The paper-based materials followed a Socratic questioning approach where small groups of students were to recognize facts, make predictions, and draw conclusions. Ruzhitskaya found that the experimental group scored significantly higher and were better able to transfer the skills to a new situation than the control group.

Working with five-year and six-year old students, Bradberry-Guest (2011), quantitatively assessed whether the supplemental Webber Interactive WH Questions educational-software program could significantly increase the ability of the subjects to answer "why" questions when compared to those that received traditional classroom-based instruction. The students were initially assessed in their ability to answer "why"

questions through the WH Question Comprehension Test, which focuses on who, what, when, where, and why questions. Those who needed assistance in developing skills in answering the subset of “why” questions were divided into an experimental group and control group. The experimental group used the software twice per week for eight weeks. The control group received traditional but unrelated instruction during that time. All subjects were then given the same WH Question Comprehension Test. The experimental group scored significantly higher on the post-test than the control group.

Powell-Laney (2010) conducted a study, using a pre-test, post-test design with post-secondary subjects in a school of nursing, that compared a human-patient simulator intervention to a paper-based case-study approach. The content was equivalent in both interventions. A human-patient simulator is a manikin that is designed to respond to stimuli as a human would. When using the simulator, students must react to the situation in real time. Prior to the pre-test, all of the students watched a video clip related to the content that was to be taught through the interventions. The simulator-approach subjects collaborated with each other during the simulation in that they participated as a team. The students then had a debriefing activity to reflect on what happened. After a lunch break, the subjects completed the post-assessment on the human-patient simulator. The case-study approach subjects collaborated with each other as a team on the case study. After the case study, the students were tested on the human-patient simulator. The students then had a debriefing activity to reflect on what happened. The clinical performance post-assessment was completed by groups of five subjects in each intervention, as opposed to each individual. The researcher assigned the group scores to each individual. The post-test consisted of multiple-choice exams that tested at the application, analysis, and synthesis levels as classified by Bloom’s taxonomy. As well, a clinical-performance evaluation was completed that compared

subjects based on the amount of time taken to recognize and intervene in the provided scenario using the human-patient simulator. Powell-Laney found that the subjects who interacted with the human-patient simulator scored significantly higher in exams and clinical performance than the group learning via paper-based case studies. However, Powell-Laney did not factor in that the human-patient simulator intervention group potentially had an advantage in that they were familiar with the simulator before the post-test while the case-study intervention group had no familiarity with the simulator. As well, the human-patient simulator intervention group had their reflective experience before completing the clinical performance evaluation while the case-study group had their reflective experience after completing the clinical-performance evaluation. Consequently, it could be expected that the human-patient simulator intervention group performed better than the case-study group on the clinical-performance evaluation, since reflection activities are recommended as an effective learning strategy (Legant, 2010; Martineau-Gilliam, 2007; Shin, 2002).

Mayrath (2009) designed a study with subjects taking a post-secondary course on computer networks, who used an educational-software tutorial to learn how to use the Packet Tracer simulation. The three treatments in the tutorial were text-only, voice-only, and voice with text. Additionally, each of the treatments were presented with either a restricted set of variables that could be controlled that was aimed at less-experienced individuals or an unrestricted set of variables that was aimed at more-experienced individuals. Based on being taught through the tutorial, transfer was assessed by how many systems the subject was able to correctly troubleshoot. There was a ten-item pre-test, a ten-minute tutorial, and then a fourteen-item post-test. There was no control group. Students were randomly assigned to one of the text-only, voice-only, and voice with text conditions. Mayrath found no significant differences in

retention or transfer except for individuals with the unrestricted set of variables who performed significantly better in the voice-only treatment than those in the text-only treatment. However, the internal consistency of the test was unacceptable. The pre-test had a Cronbach's alpha of .37 while the post-test had a Cronbach's alpha of .49, partly due to the small number of items. The general lack of a significant difference for the transfer of skills between the text-only, voice-only, and voice with text interventions may be a result of the assessed troubleshooting skills being unrelated to what was taught in the intervention, which was how to use the software.

Svenningsen (2009) conducted two experiments, on students taking an Introduction to University course, to determine whether there would be gains in critical thinking. Both experiments involved a Computer-Aided Personalized System of Instruction (CAPSI). The CAPSI program included a computer presenting learners with learning outcomes and content addressing those learning outcomes, asking the learners questions, and then providing specific and detailed feedback. The system is self-paced and progression to subsequent content occurs after the current content has been mastered. In both experiments, there were also web tools that both groups of subjects could use to communicate with the instructor and classmates, and to peer review each other's essays. In both experiments, Hegel's Dialectic was used as a means to assess critical thinking. The first experiment compared an experimental group that had a lecture and textbook readings supplemented with CAPSI to a control group that had a lecture and textbook readings supplemented with a paper-based assignment. In this experiment, the experimental group scored significantly higher on the Hegel's Dialectic measure of critical thinking than the control group. However, the results could have been affected by having four instructors teach the courses. The results could also have been affected by having thirty teaching assistants. The teaching assistants provided

feedback on the essay writing component of the intervention. The second experiment compared an experimental group that had a lecture and textbook readings supplemented with CAPSI to a control group that had a lecture and textbook readings and was assigned a research paper. In this experiment, the experimental group also performed significantly better on the Hegel's Dialectic test than the control group. Only one instructor taught the courses but there were sixteen teaching assistants. As in the first experiment, the teaching assistants provided feedback on the essay writing component of the intervention.

McMillen (2008) investigated whether strategies for playing double's tennis could be taught to adults through an educational-software intervention. The pre-test and post-test consisted of twenty true or false questions that were the same for both tests. Based on a paired samples t-test analysis of the pre-test and post-test results, McMillen found a significant increase in post-test scores.

Using the Halpern Critical Thinking Assessment Using Everyday Situations instrument in a pre-test, post-test design, Burkhart (2006) studied whether a web-based Critical Thinking Workshop tool could produce gains in critical-thinking skills in low-performing secondary-school subjects. There were two experimental groups working with the Critical Thinking Workshop tool. One experimental group participated in an explicit instructional format while the other group received embedded content of basic cognition and cognitive development through an Introduction to Psychology course. An instructor facilitated discussions with both experimental groups. Both experimental groups gained a significant amount of critical-thinking skills as compared to the control group that received neither intervention.

Katzlberger (2006) compared two educational-software approaches to teach problem-solving skills to grade-six subjects. The educational-software approaches were

identical except one approach also included the task of the subjects teaching a computer-based agent the skills. Both approaches led to a significant increase in problem-solving skills. There were no significant differences between the two approaches. Since the results were not compared to a control group, the results must be interpreted carefully.

One educational-software program for elementary-school children, called HOTS, short for Higher-Order Thinking Skills, does not directly teach higher-order thinking skills but rather relies on initiating student to student and student to teacher interactions for students to solve problems and interpret events (Pogrow, 2005; Pogrow, 1990). Pogrow (2005) stated that the HOTS program results in significant gains in mathematics, reading comprehension, and metacognition that transfer to other areas. However, Pogrow did not state in either paper that the findings are based on formal research. In a different study of the HOTS program utilized by students in grade four and five who were “at-risk” and compared to the control group taught with traditional materials, as described by (1999a) in a literature review, no significant differences were found in abstract-relation skills. However, grade-five students scored significantly higher in sequential-synthesis skills.

Using a pre-test, post-test, control-group, experimental design with adult subjects in a pilot-training program, Robertson (2005) compared a control group given traditional materials to an experimental group that received problem-based learning materials supplemented with CD-ROM-delivered training materials. Robertson found that the experimental group had significant gains in pilot performance, situational awareness, and decision making in some measurements while other measurements showed no significant gains. There was a transfer of skills in that the subjects were able to apply what was learned to a simulated testing environment. However, for the gains in

the experimental group, the study did not determine the contributing portion due to the problem-based learning approach compared to the training provided through the CD-ROM materials.

With secondary-school subjects where two of the five classrooms of subjects consisted of gifted learners, Stratton's (2003) research determined that training through educational software in a web-based instructional-delivery format, as measured through the Group Assessment of Logical Thinking tool, resulted in significant gains in logical-thinking skills as compared to traditional classroom instruction. Although both interventions covered the same chemistry content, the web-based instruction contained simulations that were not available to the subjects learning through traditional means.

Crone-Todd (2002) conducted an experiment with post-secondary students in a psychology course. The experiment had a pre-test, post-test design that used convenience samples. Within an otherwise traditionally-led course, Crone-Todd provided the experimental group with an educational-software package that presented questions of varying thinking levels and provided detailed feedback. The instructor also provided feedback with respect to the content provided by the educational-software package. The control group was taught only in the traditional way. The experimental group had significant gains in higher-order thinking skills as compared to the control group.

Fenrich (2002) created an educational-software package that was designed to teach adult piping-trades students how to use logic to troubleshoot malfunctions in hot-water heating systems. Experimental subjects, who learned through the stand-alone software, were compared to control subjects who received no additional training. All of the subjects were male. The findings of this study showed a significant increase in learning for the experimental subjects in that they were able to transfer the logical-

troubleshooting skills that they learned on the computer to determine the cause of a malfunction in real systems. Fenrich's 2002 research paralleled this study with respect to some of the instructional strategies used. For example, the elaborative feedback provided was as if an expert guided the learning through providing ideas to think about.

Kreyche (2002) created an educational-software intervention that specifically taught critical-thinking skills within a social-studies context to adults in a high-school continuing-education program. Kreyche utilised a one-group, pre-test, post-test design and found that there was a significant increase in the subjects' critical-thinking skills. Kreyche speculated that there may have been a teacher effect because the teacher was atypical to the region as he was of obviously different ethnicity than the students.

Campbell (2000) evaluated the Computer Curriculum Corporation's Successmaker educational software with grade four and five students. The software contained challenging multimedia-based problems, specific questions based on critical thinking, and a substantial reading component. Campbell found that an experimental group in one school showed an increase in critical-thinking ability after using the supplementary software while an experimental group in another school had a decrease in critical-thinking ability as compared to the control group that had no supplementary training. Factors affecting these results could be differences in administrative support, each teacher's individual ability, teacher buy-in, and each lab-facilitator's ability.

Lewis (1998) conducted a study with grade-four students to determine whether the subjects working with the educational-software program entitled The Yukon Trail would increase their critical-thinking skills. This software was integrated within a traditional teaching approach. Lewis had significant positive findings in critical-thinking skills, based on pre-test and post-test scores on the Cornell Critical Thinking Test. However, the experimental group was divided into groups of four due to the

number of available computers. This led to the experimental group using cooperative learning, whereas the control group did not. Consequently, it is not clear whether the gain in critical-thinking skills was due to the educational software, cooperative learning, or both.

With grade-twelve students, Webb (1997) assessed whether higher-order thinking skills can be enhanced through educational software as compared to the traditional lecture delivery method. Webb found that the experimental group learning through the educational software scored significantly higher with respect to higher-order thinking skills that were specific to an economics course. However, the findings could have been impacted by a teacher effect as each lecturer created and delivered their own lessons.

Using the California Critical Thinking Skills Test instrument in a pre-test, post-test, control-group design, Toth (1996) assessed whether freshman nursing students would improve in critical-thinking skills if they received a variety of instructional strategies surrounding analytical and critical thinking. Group one, the control group, worked through an educational-software package that was unrelated to developing higher-order thinking skills. Group two was taught decision making and critical thinking via educational software. Group three worked through the same educational software package as group one and also participated in instructional strategies that entailed case studies, large-group discussions, small-group activities, questioning, and role playing that emphasized critical thinking. Group four was taught decision making and critical thinking via the same educational software as group two and also participated in the same instructional strategies as group three, thereby receiving the most instruction in critical thinking. The California Critical Thinking Skills Test assessed evaluation, deductive-reasoning, inductive-reasoning, and inference skills.

Toth had mixed findings but found a significant increase in inference skills and deductive reasoning in group four, which received the most critical-thinking instruction.

Bachann (1995) found that problem-solving skills could be taught through educational software to subjects who ranged from being secondary-school students to professionals in their field. However, depending on the task, different problem-solving models were more effective than others.

With college students learning writing skills, Irwin (1995) conducted a study where the experimental group, which learned rhetorical and dialectical thinking through traditional methods combined with an educational-software program called Hermes, was compared to the control students, who learned the content only through the traditional methods. Through a qualitative assessment, the experimental group performed significantly better on rhetorical and dialectical essay writing. However, the findings may have been influenced by the researcher as the experimental-group subjects were promised that they would learn more about writing.

With college students, Mayes (1995) compared experimental subjects learning mathematics through supplemental educational software to control subjects learning mathematics in the traditional way. Mayes found that the experimental group scored significantly higher in inductive reasoning, visualizing, and problem solving. However, there were no significant differences in manipulation and computational skills between the two groups. The results were impacted by 25% of the subjects, who were randomly placed in the experimental group, opting to join the control group because of either having computer anxiety or not being willing to put in extra time to learn through the computer. Only the researcher graded the students' work. There was no external validation of the scoring, which was subjective.

With high-school students, Hurst and Milkent (1994) compared experimental subjects, who received training in predictive-reasoning skills specific to biology through a computer simulation, to control subjects, who received no training in predictive reasoning. Hurst and Milkent found that the experimental group gained significantly higher skills in predictive reasoning.

With subject's that had learning disabilities and were in grades one through six, Shiah (1994) assessed whether subjects taught through educational software would have an increase in their ability to solve math word problems. Within the educational software, one experimental group was given an explicit cognitive strategy to follow and had animated images to support the strategy while the other experimental group received the same cognitive strategy but with static images to support the strategy. The control group received a different computer-delivered problem-solving approach and had static images supporting the instructional approach. Shiah found significant gains in problem-solving skills in all three groups with no significant differences between the scores of each group. This suggests that the instructional strategies of the interventions were equally effective and that the animations were not significantly more instructionally effective than the static images.

Allison (1993) compared, in a three-year, pre-test, post-test, quasi-experimental study, an experimental group that was taught critical thinking via a problem-solving focussed intervention to a control group receiving typical remedial education. The groups were convenience samples as there was no practical way to randomly select subjects for each group. The intervention was the SMARTS educational-software program, short for Super Math and Reading Thinking Skills, that taught critical thinking/problem solving. Cooperative learning, team work, and brainstorming were important components of the SMARTS program. Parents and other teachers were also

encouraged to visit the classroom and participate in the activities. The subjects were grade three, four, and five at-risk students. The experimental subjects performed significantly better than the control subjects in math and reading skills as assessed by the Iowa Test for Basic Skills, a nationally-normed test that measures changes in “normal” academic achievement. Consequently, careful interpretation of the findings is required in that a measurement of normal academic achievement is not the same as a direct measure of the skills taught in the intervention. The findings could have been impacted by a teacher effect as the two teachers had their own style, strengths, and weaknesses.

To test the effectiveness of teaching correlational reasoning skills via computer with grade nine and ten geography students, Cousins and Ross (1993) compared subjects who learned via a task-specific computer program called CORReoGRAPH to other subjects who learned via a general-purpose computer program called WATCOM to a control group. Cousins and Ross found that the CORReoGRAPH subjects scored significantly higher in correlational-reasoning skills than the WATCOM subjects, who performed insignificantly better than the control group.

Leiker’s (1993) research, with grade three and four students, compared mathematical and higher-order thinking skills in students who were taught with supplemental educational software to those taught only through traditional means. Leiker quantitatively found that the students who worked with the supplemental educational software achieved higher scores in mathematics and higher-order thinking skills.

With students in the health-care field as subjects, Raidl (1993) compared the reasoning skills gained through a computer-based tutorial (a simulation) to a computer-based drill and practice program to a control group who had neither. The software

design was based on Dick and Carey's (1990) systematic instructional design process model. As compared to the subjects learning from the drill and practice program and the control group, Raidl found that subjects learning from the tutorial program had a significant increase in all lower-level clinical-reasoning skills (e.g., collecting information) as well as higher-level decision-making skills. However, based on the two examples described by Raidl, it appears that the drill and practice software simply tested facts regarding cardiovascular disease that did not seem to relate to the dietician decision-making skills taught in the tutorial program. If so, then it would be expected that there would not be significant gains in clinical-reasoning skills in the subjects learning from the drill and practice educational software.

With nursing students, Phillips (1992) evaluated whether an experimental group learning through educational software learned more nursing-specific critical-thinking skills than the control group learning through lecture and discussion. The educational software focused on problem-solving within simulations. Phillips found that the experimental group scored significantly higher in critical thinking than the control group, although the difference was not maintained on a follow-up post-test that was given three weeks later. However, the findings need to be carefully interpreted in that Phillips assumed that the specific higher-order thinking skills taught correlated directly with their grade-point average. In other words, Phillips did not specifically measure higher-order thinking skills.

With grade one and two students from an inner-city school, Orabuchi's (1992) study, regarding inferences, generalisations, and mathematical problem-solving, compared an experimental group that had supplemental use of numerous educational-software packages to a control group that only learned in traditional ways. The experimental subjects worked in pairs using software packages that included Animal

Rescue, Trading Post, Muppet Math, Mickey's Magic Reader, What's in a Frame?, Memory Building Blocks, Odd One Out, Hands On Math, Patterns, Reading Magic Library: Flodd The Bad Guy, and Choices Choices: Taking Responsibility. Orabuchi found that the experimental group scored significantly higher on inferences, generalisations, and math problem-solving.

Cotton (1991) reviewed five research studies, which entailed an educational software component, and found that all of the educational-software programs specifically designed to increase a student's thinking skills were able to do so. However, even though positive findings were found in each study reviewed, the overall findings were mixed in four of the five studies. The five educational-software programs focussed on analogical reasoning, logical reasoning, and inductive and deductive thinking that, in general, parallel this research. However, in contrast to this research, these programs were not stand-alone as they required significant teacher/facilitator interactions.

Using a pre-test, post-test design where subjects were randomly assigned to each treatment group, Swan (1990) assessed whether grade four to eight students would perform differently on various logical-thinking skills when provided with different types of problems to solve using the Logo programming language. One group received graphic problems, another group was given lists problems, while a third group received both graphics and lists problems. Teachers supported the students through leading discussions regarding each logical-thinking skill taught and providing guidance and feedback during the interventions. Swan found that there were no significant differences between the groups in the skills of sub-goal formation (breaking a difficult problem into two or more simpler problems), analogical reasoning (discovering a specific similarity between a given pair of words and using that similarity to match another given word to a word in a list), forward chaining (working towards the solution in a step-by-step

manner based on the information provided), backward chaining (working from a goal state and using logic to determine a pre-existing state and repeating this process until the initial state is known), systematic trial and error (the process of systematically trying possible solutions in an effort to continually reduce the number of possible solutions), and alternative representation (viewing problems from different perspectives to make the solution obvious). However, there were significant gains in five of the six skills. These skills included sub-goal formation, analogical reasoning, forward chaining, systematic trial and error, and alternative representation but not backward chaining. Swan also found that there was a significant increase in transfer of learning. Swan did not determine which part of the intervention (i.e., working with Logo, teacher-led discussions, and/or teacher guidance and feedback) led to the gains. Due to the lack of a control group, these findings must be carefully interpreted.

Duffield (1989) assessed whether grade three and four students could learn problem-solving skills from the educational-software packages called the King's Rule, which taught specific skills used in math and social studies, and Safari Search, which taught problem solving through puzzles. The subjects in Duffield's study generally worked individually but also helped each other as needed. Through both a quantitative and qualitative analysis, Duffield found that the subjects gained some problem-solving skills that the software specifically addressed, subjects devised their own unique strategies to solve the presented problems, and no significant near or far transfer of skills. However, since Duffield did not have a control group, interpretation of the findings must be done carefully.

With grade seven and eight, private school students, Galinski (1988) evaluated the effectiveness of an educational-software program called The Factory. The experimental group interacted with The Factory software while the control group spent

time on a variety of irrelevant computer activities. Both the experimental and control groups received traditional mathematics instruction. Galinski found that both groups gained in mathematical problem-solving, analysis, and synthesis ability. Galinski also found no differences between the computer-based training and traditional instruction groups with respect to mathematical problem-solving, analysis, and synthesis ability but did find that the control group had an increase in spatial ability. It is possible that the gains were due to the traditional instruction given rather than the educational-software intervention.

Grossen (1988) used educational software to specifically teach reasoning skills to learning-disabled, grades nine through twelve high-school students. Based on pre-test and post-test scores, Grossen found a significant increase in the subjects' reasoning skills when taught via the software program. Grossen stated that the subjects' reasoning skills were increased to a level comparable to college students and high-school gifted students. However, if the college and high-school gifted students did not receive any training in reasoning skills, their reasoning skills could have been poorly developed (Astleitner, 2002; El-Sanhurry, 1990; Kreyche, 2002; Raidl, 1993). Grossen also found that the skills learned transferred beyond the context in which the content was taught. However, the amount of gain decreased as the similarity of the test questions to what was taught decreased. The subjects were classified as "learning-disabled" based on standardised achievement scores. Although the subjects' mean standardised achievement scores corresponded to grade six, it would be unsafe to generalise Grossen's findings to the "normal" grade six and seven students of this study.

With post-graduate nursing subjects, Tilson (1986) compared two educational-software programs, where one program had extra critical-thinking content embedded within Gagné's Events of Instruction. The embedded critical thinking was taught by

presenting learners with the theoretical framework of critical thinking, giving general rules for thinking critically, modelling, and allowing for practice and feedback. The content was presented entirely through the educational software. Tilson found that both the regular and enhanced program showed equal gains in critical-thinking skills. This may be because both programs had excellent instructional design that already adequately addressed critical thinking, making the extra critical-thinking training redundant. Although Tilson's interventions were designed around Gagné's Events of Instruction like the interventions of this research, there were foundational differences in their design. Tilson's educational software is text-only, the instructional strategies are different, and student responses included fill-in-the-blank and short-answer questions. One similarity to the interventions of this research was that Tilson's educational software provided detailed feedback to support learning.

Chapman (1985) evaluated whether clinical-reasoning skills could be effectively taught through educational software to second-year medical students. As compared to the control group, the experimental subjects received three extra hours of instruction through a computer simulation. Although Chapman had mixed findings for the different hypotheses, the experimental group showed statistically significant increases in reasoning skills. The findings may have been impacted by the week-long duration of the study since the experimental and control groups had contact with each other.

Collins (1984) used educational software to teach formal logic via syllogistic arguments with academically-challenged secondary-school students. Collins compared experimental subjects using software that provided elaborative feedback to control subjects learning from software that only provided basic feedback. The results showed that there were large gains in formal-logic skills for both groups, with a bigger difference for the experimental group. These results were achieved even though the

user-interface had weaknesses in that students had to remember information from previous screens to answer questions on the current screens and subjects with slower reading speeds may not have been able to read all of the elaborative feedback as the program automatically moved to the next screen after a fixed amount of time.

Non-significant Findings through Educational Software

The following studies illustrate that learning through an educational-software intervention can result in no significant differences with respect to a learner's higher-order thinking skills.

In a pre-test, post-test, experimental design, Peterson (2012) compared the situational decision-making skills that an experimental group gained through learning from a computer simulation to a control group learning the same skills through traditional means. The subjects were experienced nurses. Peterson found no significant differences between the two groups. Given Cronbach alpha values of -0.282 for the pre-test and 0.207 for the post-test, the researcher-made tests had unacceptable internal consistency.

Through a quantitative analysis, Fanetti (2011) found that college students did not show any gains in reasoning skills after playing the video games entitled Professor Layton and the Curious Village and Professor Layton and the Diabolical Box. This was assessed through the analytical section of the General Graduate Record Exam. As well, Fanetti qualitatively found that the students tended to use trial and error as their main approach to solving puzzles rather than recognizing when to use reasoning skills to solve the puzzles.

Carwie (2010) used the Computer-Supported Argument Mapping educational-software program to teach the experimental group critical-thinking skills while the control group was assigned a traditional essay writing activity to enhance their critical-

thinking skills. Both groups also received traditional instruction. The subjects were undergraduate nursing students enrolled in a community-nursing course. This quasi-experimental research used the Health Sciences Reasoning Test as both the pre-test and post-test to determine whether the intervention led to a significant difference in critical-thinking skills between the two groups. No significant differences between the two groups were found. Neither group had a significant increase in scores. The findings could have been impacted from having a different teacher for each of the groups as they may have had differing skills in ability to teach critical thinking and different teaching styles. As well, the findings may have been impacted by the experimental and control group subjects being on different campuses. The findings were affected by high mortality as only 57 of 78 experimental students completed the research requirements (i.e., the pre-test and post-test) while only 42 of 61 control group subjects completed the requirements.

Using a convenience sample of students in three schools where the students were pursuing a Bachelor's degree in nursing, Shinnick (2010) compared experimental subjects who were trained with a human-patient simulator and who had a debriefing session to a control group who did not interact with the human-patient simulator and did not have a debriefing session. The human-patient simulator was programmed to respond like a real patient. The Health Sciences Reasoning Test was used as the assessment tool. It assesses an individual's ability in deductive and inductive reasoning, evaluation, analysis, and inference. As compared to the control group, Shinnick found that the experimental group had a decrease in reasoning skills after working with the simulator and significant gains in reasoning skills after the discussions in the debriefing sessions.

Using a controlled experimental research design, Baumer (2009) compared experimental subjects, who were taught in a traditional way but also received

supplementary computer-delivered instruction, to control-group subjects, who were also taught in a traditional way but also received additional traditional materials, such as video clips. The supplementary computer-delivered instruction was embedded in a grade-seven cell-biology module. The software analyzed, with respect to metaphor usage, the subject's answers to typical questions and then provided questions leading students to create their own metaphors. Baumer found no significant differences with respect to metaphorical reasoning, creativity, or ability to transfer knowledge beyond what was taught. Results were only analyzed for students who answered at least half of the initial questions asked. This may have skewed the results towards higher-achieving students. Baumer speculated that there may have been a novelty effect as it was highly unusual for the students to have a researcher from the university come to their classroom and ask them to answer relatively unusual questions presented on a computer.

In 2008, Morey assessed whether content supplemented with life-like pedagogical agents that interacted with nursing-student subjects by providing feedback, guidance, and encouragement would lead to an increase in skills as compared to control subjects who did not experience the pedagogical agent. Although Morey found no significant differences regarding making an appropriate diagnosis or a correct conclusion using the Critical Thinking Process Test, qualitatively she did find a significant increase in the experimental group's ability to think critically and to make appropriate evaluations.

Schüblová (2008), in a non-experimental design, assessed whether a self-directed, computer-delivered, problem-based learning intervention would increase the subjects' critical-thinking ability as measured through scores on the California Critical Thinking Skills Test and the subjects' performance on a computer simulation entailing the evaluation of athletic injuries. The subjects were post-secondary athletic-training

students. Schüblová did not find significant gains in critical thinking or in the subject's ability to evaluate athletic injuries.

Mackenburg-Mohn (2006) compared the effectiveness of teaching critical thinking through educational software to students learning the skills through traditional methods. The educational-software package presented four case studies to the experimental group. The subjects were nursing students. Mackenburg-Mohn found no significant increases or decreases in critical-thinking skills over time. The specific thinking skills measured were truth seeking, open-mindedness, ability to analyse, ability to be systematic, and inquisitiveness. Mackenburg-Mohn's findings could have been affected by the small number of case studies presented in the software as there may have been significant gains if more case studies were presented.

With subjects in a high school taking a year-long geometry course, Subramanian (2005) investigated whether experimental subjects taught through traditional means but supplemented with dynamic geometry software would gain in logical-thinking and proof-constructing skills as compared to a control group who received the same traditional teaching but did not use the software. The dynamic geometry software, entitled Geometer's Sketchpad, enabled subjects to assess the validity of their proofs. Subramanian found no significant differences in logical-thinking and proof-constructing skills between the groups. A contributing factor to the findings may have been that the software does not specifically teach logical-thinking or proof-construction skills.

Through a pre-test, post-test, control-group design with grade nine through twelve subjects, Shin (2002) evaluated whether experimental subjects taught through educational software combined with Internet research and virtual discussions would gain in critical-thinking and art-critiquing skills as compared to a control group that had no intervention. The educational software contained lessons on art vocabulary and

thinking, discussing, and writing essays about art. Shin found no significant differences in the critical-thinking and art-critiquing skills between the experimental and control group.

Rendall (2001) conducted a study that evaluated the effectiveness of the INVEST educational-software product as compared to traditional methods of instruction with fourteen to seventeen year-old subjects in a remedial program. Rendall found that, although students learning from the supplementary software scored significantly higher on numerical operations (which are not higher-order thinking skills), there was no significant increase in mathematical-reasoning skills. This was somewhat expected given that the INVEST software is mainly a drill and practice program.

Mintz (2000) compared an experimental group of grade four and five students learning mathematics from the Successmaker educational software to learning mathematics using traditional classroom teaching methods. Mintz found that after one year of use, students learning from the supplemental software did not have any significant performance gain in critical thinking over the control group. Factors that may have contributed to the lack of an increase in learning through the software include a lack of teacher training, a lack of teacher buy-in as it required the teacher to give extra time, a mismatch between how the content is taught by the software and the teacher, and differences between the content in the software and that of the curriculum. Mintz's findings differed from Campbell's (2000) findings regarding the Successmaker software, which are described above, in that Campbell reported significant gains in one experimental group and a significant decrease in another experimental group.

Rothman (2000) evaluated whether an educational-software game, entitled *The Voyage of the Mimi*, could lead to increases in critical thinking compared to traditional methods of teaching grade-five students. Rothman found that the experimental group

had a higher positive trend in critical thinking, although the results were insignificant. Rothman did not describe whether the software focussed on critical thinking or facts.

Ellingwood (1999) evaluated the effects of Logo programming language instruction on higher-order thinking skills on grade-one students. Experimental students were initially taught keyboarding and other basic computer skills. These students were then taught mathematics through Logo programming. The control group was taught mathematics by traditional methods. Ellingwood found that the experimental group had higher mean gains in higher-order thinking skills but these gains were insignificant. Ellingwood minimized the teacher effect by training the teachers to follow scripts.

McKenzie (1999) assessed the effectiveness of the Learning Logic educational-software program on subjects in grades nine through twelve. The experimental group learned via the Learning Logic software in a self-paced mode. The control group learned mathematics by traditional teaching methods. McKenzie found that the control group scored significantly higher in mathematics achievement. Not enough information was provided to assess whether the software's instructional design was effective or not.

For a post-secondary environmental geology course, Frear (1997) assessed whether an experimental group receiving twenty-five hours of interactive computer-based simulation would develop a higher level of logical-thinking skills than the control group that did not experience the intervention but instead participated in traditional labs. Rather than random assignment into groups, Frear used intact groups. Based on pre-test, post-test results on the Group Assessment of Logical Thinking instrument, there were no significant differences in logical-thinking skills between the groups. Frear did not report whether each group had a significant gain in logical-thinking skills.

Lafferty (1996) used a quasi-experimental, pre-test, train, post-test design with an experimental and control group of grade-four subjects in a mainstream public school

to determine whether experimental-group subjects who worked through the Structure of Intellect educational-software program in addition to their normal coursework would perform better on the assessment tool contained with the software as well as the Standard Achievement Test than the control group that only received their normal coursework. The Structure of Intellect resource is a training program that develops over twenty different cognitive skills, such as problem-solving. The intervention supported different modalities for learning, identified weak skill areas, and gradually developed the skills. Lafferty found no significant differences before and after the intervention with respect to performance scores as well as transfer of learning.

With grade-seven science students in a private school who had a mean IQ of 123 as assessed through the Otis-Lennon Test of Mental Measurement, Schmidt (1991) evaluated whether students who used the Weather Prediction expert system as well as traditional materials would gain in weather-prediction skills. The software used was an expert system entitled Weather Prediction. The subjects also learned about weather through textbook readings, discussions, taking actual weather measurements, and entering measurements into the expert system to see the system's weather prediction. They were asked, based on data, to make their own predictions and compare those to the computer's predictions based on logic rules contained within the expert system. Subjects could also enter "Why?" to receive an explanation of the results and enter "What if?" questions to determine how changing a variable impacted the weather prediction. Using a self-designed weather-prediction test, the Test of Logical Thinking, and a test from the textbook, Schmidt found no significant differences in scores based on comparing pre-test to post-test scores. The lack of significant findings may have been due to there being more variables impacting predictions than the subjects could mentally handle. The low scores support this possibility.

Yuill (1991) assessed whether a computer-based problem-solving simulation could improve critical-thinking skills in undergraduate nursing students. Using the Watson-Glaser Critical Thinking Appraisal tool, Yuill found that the intervention did not lead to any significant change in critical-thinking skills.

With secondary-school, grade nine through twelve, at-risk subjects enrolled in a reading improvement program, Sykes (1990), using a quasi-experimental, pre-test, post-test design, compared three interventions to a control group. All groups received teacher-based instruction, reading materials, and computer-assisted instruction within a reading class. The intervention emphasized self-esteem, critical thinking, or self-esteem combined with critical thinking. The experiment took place for ten minutes per day for five weeks. However, the experimental self-esteem and critical-thinking group alternated between working on self-esteem and critical thinking each day. This may have impacted the results as this reduced the training time for each by half as compared to the other experimental group. The pre-test and post-test evaluation assessed reading comprehension, self-esteem, and critical thinking. Subjects were pre-assessed before the experiment using the Test of Non-verbal Intelligence to factor in any initial differences between the groups. This may also have influenced the findings as this test measured different skills than the instruments used for the post-test. Using the Standard Diagnostic Reading Test, Piers-Harris Self-Concept Scale, and Cornell Critical Thinking Test, Sykes found no significant differences or gains between the groups in reading comprehension, self-esteem, or critical thinking.

Repman (1989) assessed whether different commercially-available software packages (Bank Street Writer, U.S. History Databases, Where in the U.S.A. is Carmen San Diego?, Ten Clues, Crossword Magic, and SuperPrint!) could be used to teach critical-thinking skills to grade-seven students. Repman found no significant differences

between the experimental and control groups. However, Repman did not evaluate the instructional strategies of the software and then assess whether or not the software should be able to teach critical-thinking skills. Consequently, the findings should not necessarily be generalized to other educational software.

With baccalaureate nursing students, Pond (1987) evaluated whether critical thinking could be enhanced through educational software and lecture. Pond found that a learner's critical-thinking ability was not enhanced through educational software or lecture. There was likely some emphasis on lower-level skills since Pond found that the experimental subjects who used the educational software had an increase in knowledge and retention of knowledge but not more than lecture. Although the instruction was based on Gagné's Events of Instruction, simply following Gagné's Events of Instruction does not in itself ensure that critical thinking is taught. For example the results could have been impacted if the learning outcomes, instructional strategy, and feedback did not focus on higher-order thinking skills, as is a possibility given the results. Pond's study relates to this research in that both follow Gagné's Events of Instruction. However, Pond's study differs from this research in the instructional strategies used.

Bass and Perkins (1984) used educational software to attempt to teach grade-seven students the thinking skills of verbal analogies, logical reasoning, inductive/deductive reasoning, and word-problem analysis. As compared to traditional teaching methods, Bass and Perkins found that the educational software led to increased but not statistically significant skills in verbal analogies and inductive/deductive reasoning. There were no differences in logical reasoning and word-problem analysis.

Using a pre-test, post-test, experimental design with private-school kindergarten subjects who were pre-screened to be accepted into the private school with the requirement to be average or higher with respect to cognitive development, vonStein

(1982) compared an educational-software tutorial to a traditional approach for teaching how to sequence shapes and found no significant differences between the experimental and control groups. Both groups gained in performance, albeit not significantly.

Summary: Findings through Educational Software

In summary, the literature distinctly showed that subjects can learn higher-order thinking skills through educational-software interventions. However, positive findings were not automatic as some studies had mixed findings while others showed no significant gains. The majority of the above interventions were stand-alone. Of the above studies, none closely matched this research study. This was in respect to whether or not the intervention aimed to teach the same logical-thinking skills, followed a related instructional strategy, and had subjects in grade six and seven.

None of the educational-software interventions tried to teach all of the same logical-thinking skills as in this research, which included the skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning. Most of the interventions attempted to teach entirely different skills, such as generic critical-thinking or higher-order thinking skills. Three interventions assessed deductive-reasoning skills, although the deductive-reasoning skills that were described in those interventions were different. One intervention focused on sequencing skills. However, the sequencing skills in that intervention focused on sequencing shapes, as opposed to the sequencing of numbers in this research. The sequencing shapes activity was at a simple level of ability as the activity was aimed at kindergarten subjects. Another difference to this research is that some of the interventions of other studies involved content-specific higher-order thinking skills as opposed to the generic higher-order thinking skills. Three researchers discussed interventions regarding analogical-reasoning skills.

With respect to the interventions that aimed to teach the same skills that were studied in this research, no specific details on instructional strategies were found. Swan's (1990) instructional strategy for teaching analogies was based on Logo programming and consequently would not apply to this research. Cotton (1991) and Bass and Perkins (1984) did not describe the instructional strategy of the intervention for teaching analogical-reasoning skills. For the intervention regarding a sequencing skill, vonStein (1982) did not describe the instructional strategy used.

In only a few of the studies did the researcher consider whether the instructional strategies of the educational software followed established principles of educational theory. As such, in some studies, it may have been that students did not learn higher-order thinking skills because of poor instructional design as opposed to it not being possible to teach higher-order thinking skills by educational software. In general, from the brief descriptions of the instructional strategies that were provided by researchers, one could only speculate on generalities of effective principles of instructional design. As one example, the strategy of practice with elaborative feedback seemed to be effective in teaching higher-order thinking skills.

None of the studies only had subjects in both grade six and seven. One study involved grade-six students, four had grade-seven students, and one had students in grade seven and eight. Only one of the six interventions, Bass and Perkins (1984), tried to teach a skill that was the same as this research. The skill was analogical reasoning and no significant gains were found. Only two of the above six studies led to at least some significant gains in higher-order thinking skills.

2.7.2 Paper-based Materials

Only two studies were found that used a stand-alone paper-based intervention that aimed to teach and assess gains in higher-order thinking skills.

Using the Primary Education Thinking Skills™ (PETS) program as an intervention with elementary-school subjects, Thomson (2009) assessed whether experimental subjects exposed to the supplemental use of the program would lead to increased scores on the Screening Assessment for Gifted Elementary and Middle School Students – Second Edition (SAGES-2), which assesses reasoning skills, as compared to control subjects who did not use the PETS program. The lessons in the PETS program were paper-based and focused on analysis, synthesis, evaluation, and visual-spatial thinking skills. The pre-test was given as the subjects entered grade one and the post-test was given as the subjects completed grade three. Quantitatively, Thomson found no significant differences in reasoning skills. However, given the duration of the study, the control and experimental subjects may have been taught reasoning skills through other means over the three years. Near the end of the intervention, a qualitative assessment was conducted, through interviewing the students in the experimental group and their teachers, to assess their perceived impact of the PETS program. The overall perception was that the program positively and significantly impacted higher-order thinking skills. This is in contrast with the quantitative data.

Using a post-test only, quasi-experimental design with adults taking an introductory educational-technology course, Lee (2008) wrote online-discussion transcripts for each group to read. The control group read expository text whereas one experimental group read high-level discussion transcripts while the other experimental group read low-level discussion transcripts. None of the groups participated in a discussion. The participants of each group wrote their responses to the transcripts in an essay. Through qualitative assessment using a scoring rubric, Lee found that the experimental group that read high-level discussion transcripts scored significantly higher in critical-thinking skills than the other two groups, based on scores using the

whole rubric. There were no significant differences in critical-thinking skills based on individual rubric items. However, there was no random assignment of the subjects to each group. Significant differences in quiz scores taken before the experiment took place were found between the control group and the low-level discussion group. Nonetheless, the findings suggest that students can learn vicariously by reading the contributions of others. For example, this can occur in an online environment when students read the discussion forum contributions of their classmates.

Neither Thomson (2009) nor Lee (2008) described the instructional strategies used in the interventions. However, given the ages of the subjects and the different subject matter, the instructional strategies would not have provided direct guidance in how to design the interactions of this research.

Summary: Findings through Paper-based Materials

The literature was sparse and the findings were mixed. One study showed that subjects could learn higher-order thinking skills through a stand-alone paper-based intervention while the other did not. Of the above studies, none closely matched this research study in terms of the intervention aiming to teach the same logical-thinking skills, following a related instructional strategy, and having subjects in grade six and seven.

2.8 Findings for Comparable Interventions

This research compared gains in logical-thinking skills through an educational-software intervention to a highly similar paper-based intervention. Theoretically, should there be any differences between the two interventions?

2.8.1 Expected Results for Comparable Interventions

In a landmark paper, Clark (1983) stated,

Consistent evidence is found for the generalization that there are no learning benefits to be gained from employing any specific medium to deliver instruction. Research showing performance or time-saving gains from one or another medium are shown to be vulnerable to compelling rival hypotheses concerning the uncontrolled effects of instructional method and novelty (p. 445).

According to Singh (2010), Clark over the years has “maintained that technology in and of itself cannot improve learning outcomes” (p. 2) over content taught in a traditional way. In other words, if the content is presented through two modes of delivery that follow the same instructional strategy, the findings should be the same. This is also consistent with Semper Scott (2005) who stated that minor differences in the learning experience do not result in significant differences in performance. In agreement with Clark’s (1983) conclusion, Cott (1991), Larson, Britt, and Kurby (2009), Shiah (1994), and Titterington (2007) each had findings that showed no significant differences with comparable interventions, as described above. The findings of Heo (2012) and Cott (1991) also support Clark’s conclusion, as described below.

Heo (2012) assessed whether there were any comprehension differences between college students, taking an online Health Counseling Psychology course, taught with video-based instruction, audio-based instruction, or text-based instruction. Using an assessment tool created by the researcher, Heo found no differences in comprehension between the three groups. Heo (2012) also expected insignificant differences between the groups given the statement, “If an instructional method promotes the same kinds of cognitive processing across different media, then it will also result in the same benefits across media (Mayer, 2003)” (p. 30). With respect to similar interventions, such as paper-based or educational-software materials, Heo (2012) stated

that different delivery methods do not change the basic nature of how the brain works. Rather, the design of the instructional strategies used will impact how much learning occurs.

Cott (1991) designed a study, with college students, where the experimental group was taught logic skills via a programmed instruction booklet and the control group was taught the same skills via traditional text. The programmed instruction and text versions were designed to closely match each other. Quantitatively, Cott found no significant differences in achievement between the two groups. Cott did not conduct pre-tests and, consequently, did not report whether each group had a significant increase in the amount learned.

In further support of Clark, Rodriguez (2009) stated,

Current research indicates that students do learn equally from an online environment, which also includes a blended format, and from a traditional face to face environment (Bello, 2005; Johnson, 2000; Phipps & Merisotis, 1999) if the environments follow learner centered best teaching practices (Duffy & Kirkley, 2004; Weimer, 2002) (p. 3).

Although Rodriguez did not state that the instructional strategies must be identical, Rodriguez implied that if content is taught well in one way and the same content is also taught well in another way, students will learn equally well from either instructional approach.

2.8.2 Educational Software Compared to Paper-based Interventions

There were relatively few research studies on teaching higher-order thinking skills that compared an educational-software intervention to a paper-based intervention.

Larson et al. (2009), using a post-test only design, assessed whether claim-reason argumentation could be taught to both secondary and post-secondary students through stand-alone paper-based and educational-software tutorials. As compared to the control group that did not receive the tutorial, the subjects in both experimental groups

had a significant increase in the ability to detect flawed arguments. The increases between the two groups were comparable. Similarly, Larson et al. found similar gains with a web-based tutorial that closely paralleled the educational-software version.

Titterington (2007) quantitatively found significant gains in higher-order thinking skills through both a traditionally-delivered paper-based intervention and a comparable online-delivery intervention. Titterington's study entailed post-secondary allied-health students studying pathophysiology. In both interventions, the content was taught through case studies. Titterington's instructional strategy was not entirely stand-alone as instruction delivered in a traditional way was also a part of the interventions. Both groups had similar results.

With first-year post-secondary students who were being tutored in a course they had previously failed, Bessick (2008) compared the critical-thinking skills from learning from an educational-software package called the Rationale Argument Mapping Program to learning from a paper-based package called The Thinker's Guides. The Rationale Argument Mapping Program was based on an interactive approach that guided, built, and evaluated an individual's ability to make arguments. The Thinker's Guides were based on Richard Paul's model of critical thinking and were designed to help students "identify general concepts related to critical thinking and specific critical thinking skills necessary to think effectively for different disciplines and tasks" (Bessick, 2008, p. 57). The two interventions are not directly comparable in that the instructional strategies of these two resources are distinctly different. Using the California Critical Thinking Skills Test as the assessment tool, Bessick found that neither experimental group showed a significant increase in critical-thinking skills.

Of the above studies, none closely matched this research study in terms of aiming to teach the same logical-thinking skills via both an educational-software and a

paper-based intervention, following a related instructional strategy, and having subjects in grade six and seven. None of the researchers, who assessed comparable interventions, provided details about the instructional strategies that they used in their interventions.

Summary: Findings Regarding Comparable Interventions

The literature generally supported that comparable interventions that aim to teach higher-order thinking skills should have similar findings. Consequently, for this research, where the instructional strategies in the educational-software and paper-based interventions were essentially identical, it was expected that there would be no significant differences between those two groups.

2.9 Research on the Transfer of Thinking Skills

The following studies addressed higher-order thinking skills and specifically assessed transfer of learning. Each of these studies is discussed in more detail above.

2.9.1 Transfer of Skills through Educational Software

Using an experimental pre-test, post-test design without a control group and first and second-year physician-assistant students as subjects, Meyer (2010) compared two interventions. One intervention was a computerized problem-based learning approach that included authentic case studies as well as media components such as radiograph images, audio clips of heart and lung sounds, and video clips of ultrasound imagery. In this intervention, subjects could select questions to find out information about the patient in the case study and receive answers. The other intervention was a human-patient simulation where a mannequin was programmed to respond like a human, based on the facts of the case study. The subject took the measurements needed, made decisions, such as giving a medication, and saw the corresponding response. Using the

Learning Transfer Systems Inventory, Meyer found no increases in pre-test to post-test scores and no difference in learning transfer performance between the two groups. Through a qualitative analysis, students in both groups thought that they were able to transfer the skills learned.

Mayrath (2009) designed a study with post-secondary subjects who used an educational-software tutorial to learn how to use the Packet Tracer simulation. The three treatments in the tutorial were text-only, voice-only, and voice with text. Additionally, each of those were presented with either a restricted set of variables that could be controlled that was aimed at less-experienced individuals or an unrestricted set of variables that was aimed at more-experienced individuals. Based on being taught through the tutorial, transfer was assessed by how many systems the subject was able to correctly troubleshoot. Mayrath found no significant differences in retention or transfer except for individuals presented with the unrestricted set of variables who performed significantly better in the voice-only treatment than those in the text-only treatment.

Katzlberger (2006) compared two educational-software approaches to teach problem-solving skills to grade-six subjects. The educational-software approaches were identical except one approach also included the task of the subjects teaching a computer-based agent the skills. Katzlberger only found a significant increase in the transfer of skills with the instructional approach that required subjects to teach a computer-based agent.

The Higher-Order Thinking Skills (HOTS) educational-software program for elementary-school children, does not directly teach higher-order thinking skills but rather relies on initiating student to student and student to teacher interactions for students to solve problems and interpret events (Pogrow, 2005; Pogrow, 1990). Pogrow

(2005) stated that the HOTS program results in significant gains in mathematics, reading comprehension, and metacognition that transfer to other areas.

With adult subjects in a pilot-training program, Robertson (2005) compared a control group given traditional materials to an experimental group that received problem-based learning materials supplemented with CD-ROM-delivered training materials. Robertson found that the experimental group had a transfer of skills in that the subjects were able to apply what was learned to a simulated testing environment.

Fenrich (2002) created an educational-software package that was designed to teach adult piping-trades students how to use logic to troubleshoot malfunctions in hot-water heating systems. Experimental subjects, who learned through the software, were compared to control subjects who received no additional training. The findings of this study showed that the subjects were able to transfer the logical-troubleshooting skills that they learned on the computer to real systems.

Swan (1990) assessed whether grade four to eight students would perform differently on various logical-thinking skills when provided with different types of problems to solve using the Logo programming language. One group received graphic problems, another group was given list problems, while a third group received both graphics and list problems. Teachers supported the students through leading discussions and providing guidance and feedback during the interventions. Swan found that there was a significant increase in transfer of learning.

Duffield (1989) assessed whether grade three and four students could learn problem-solving skills from the educational-software packages called the King's Rule, which taught specific skills used in math and social studies, and Safari Search, which taught problem solving through puzzles. Through a qualitative analysis for both software programs, Duffield found no significant gains in near or far transfer of skills.

Grossen (1988) used educational software to specifically teach reasoning skills to grades nine through twelve high-school students. Based on pre-test and post-test scores, Grossen found that the skills learned transferred beyond the context in which the content was taught. However, the amount of gain decreased as the similarity of the test questions to the material taught decreased.

With grade-seven subjects, Baumer (2009) compared experimental subjects, who were taught by traditional methods of teaching but also received supplementary computer-delivered instruction, to a control group, which was also taught by traditional teaching methods but also received additional traditional materials. The software analyzed, with respect to metaphor usage, the subject's answers to typical questions and then provided questions leading students to creating their own metaphors. Baumer found no significant differences in ability to transfer knowledge beyond what was taught.

With grade-four subjects, Lafferty (1996) compared experimental-group subjects, who worked through the Structure of Intellect educational-software program in addition to their normal coursework, to the control group, which only received their normal coursework. The Structure of Intellect resource is a training program that develops over twenty different cognitive skills, such as problem-solving. Based on the Standard Achievement Test the assessment tool contained within the software, Lafferty found no significant differences before and after the intervention with respect to transfer of learning.

2.9.2 Transfer of Skills through Paper-based Materials

There were no studies found that assessed the transfer of higher-order thinking skills through stand-alone paper-based materials. Similarly, there were no studies found

that compared the transfer of higher-order thinking skills in a stand-alone paper-based intervention to a stand-alone educational-software intervention.

Summary: Research on the Transfer of Thinking Skills

In summary, the findings generally supported that higher-order thinking concepts learned through educational software can be transferred to other problems or situations. However, given some mixed findings and some studies resulting in no transfer, one cannot assume that the transfer of learning of higher-order thinking skills would take place. As a comparison to this research, none of the studies regarding the transfer of higher-order thinking skills matched with respect to the specific skills taught, the subject's age, and teaching through a stand-alone intervention. No studies were found regarding a stand-alone paper-based intervention that assessed the transfer of higher-order thinking skills. Similarly, there were no studies found that compared an educational-software intervention to a stand-alone paper-based intervention that assessed the transfer of higher-order thinking skills.

From an instructional design perspective, Hurte (2004) suggested that the far transfer of higher-order thinking skills is facilitated when individuals can apply the skills in their professional or personal lives while Rocks (2004) stated that transferring higher-order thinking skills is enhanced when a learner has developed a deep level of connected learning with respect to those skills. Both Hurte (2004) and Lafferty (1996) asserted that extensively practicing the skills in a variety of ways was also important. Meyer (2010) stated that as the similarity between learning situations increased, the amount of transfer increased. Grossen's (1988) findings supported Meyer's statement. Lafferty (1996) extended what Meyers (2010) stated as she noted that success was more readily achieved with near-transfer skills, modeling may not have been enough to elicit a gain in far-transfer skills, and an increase in the ability to transfer skills required a

deliberate effort, particularly for far-transfer skills. Similarly, Christian (1995) suggested that the transfer of higher-order thinking skills would only occur if an instructional intervention was specifically designed to facilitate the transfer of skills. Although these generalities were provided, none of these researchers provided details regarding how his or her instructional strategies facilitated the transfer of learning.

Researchers who had significant positive findings when measuring gains in higher-order thinking skills as measured by commercial assessment tools may have actually measured gains in far-transfer skills because these tools assessed specific thinking skills that did not necessarily reflect the content that is taught in an intervention (Commeyras, 1991; Terry, 2007). If the skills assessed were different than those taught then, by definition, far-transfer skills would have been assessed. Note that the studies presented in this section only included those where the researcher specifically stated that transfer of learning was being assessed. It was only speculation that led to the suggestion that other studies actually assessed far-transfer skills.

2.10 Literature Review Findings Summary

The literature supported that higher-order thinking skills can be taught through educational-software interventions. However, positive findings were not certain as some studies had mixed findings while others showed no significant differences. Although the majority of the interventions were stand-alone, none closely matched this research study in that the interventions did not teach the same logical-thinking skills, follow a related instructional strategy, and have grade six and seven subjects. Only general principles of effective instructional design could be discerned.

Only two studies were found on teaching higher-order thinking skills through stand-alone paper-based interventions. One study showed that subjects can learn higher-order thinking skills through a stand-alone paper-based intervention while the other did

not. Neither study closely matched this research in terms of the intervention aiming to teach the same logical-thinking skills, following a related instructional strategy, and having grade six and seven subjects.

The literature supported that comparable interventions that aimed to teach higher-order thinking skills should have similar findings. Of the studies found, none closely matched this research in terms of aiming to teach the same logical-thinking skills via both an educational-software and a paper-based intervention, following an equivalent instructional strategy, and having grade six and seven subjects.

The research clearly showed that children and adolescents of varying ages can learn a variety of higher-order thinking skills. However, learners must have the foundational knowledge needed to learn the skills addressed in the interventions. Specifically, based on Piaget's theory of cognitive development, Vygotsky's Zone of Proximal Development model, and research findings, subjects in grades six and seven, respectively aged eleven and twelve years old, were expected to be able to learn the classification, analogical-reasoning, sequencing, and deductive-reasoning skills from the educational-software and paper-based interventions of this research. No studies were found regarding teaching the patterning skill of this research.

The findings generally supported that higher-order thinking concepts learned through educational software can be transferred to other problems or situations. However, given some mixed findings and some studies resulting in no transfer, one cannot assume that the higher-order thinking skills learned will transfer. As a comparison to this research, none of the studies regarding the transfer of higher-order thinking skills matched with respect to the specific skills taught, the subject's age, and teaching through a stand-alone intervention. No studies were found regarding a stand-alone paper-based intervention that assessed the transfer of higher-order thinking skills.

Similarly, there were no studies found that compared an education-software intervention to a stand-alone paper-based intervention that assessed the transfer of higher-order thinking skills. The transfer of higher-order thinking skills was more likely to occur with near-transfer skills than far-transfer skills.

The instruments typically used to measure higher-order thinking skills would not inherently measure all of the specific logical-thinking skills addressed in this research and not in the same context for the same age group. Consequently, none of the commercial instruments were appropriate for this study.

With respect to all of the studies found, this research was unique for a number of reasons. Most of the studies evaluated different types of higher-order thinking skills rather than specifically measuring logical-thinking skills. Of the studies that assessed logical-thinking skills, none measured the same skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning as was done in this research. Some of the existing research was different because higher-order thinking skills were specifically taught within a field like nursing or a subject like mathematics, accounting, or economics, rather than teaching generic logical-thinking skills. Many of the studies found did not utilize a stand-alone intervention. Many of the studies involved secondary and post-secondary students while few studies involved grade six and seven students, the subjects of this study. A small number of studies compared an educational-software intervention to a paper-based intervention. However, the paper-based interventions were different than this study as they were not stand-alone interventions. A relatively small number of researchers measured the transfer of learning of higher-order thinking skills. In general, the instructional strategies and activities within the interventions created for this research were unique in that they were not copied from any other intervention, albeit some ideas, such as providing elaborate feedback, were found in other studies.

Specifically, the instructional strategies for teaching analogical reasoning had similarities to some of the instructional strategies found in the literature. No instructional strategies, suitable for the subjects of this study, were found for teaching classification, sequencing, patterning, and deductive-reasoning skills. The lack of studies found regarding instructional strategies or instructional design was consistent with Wruck (2010) who stated that “there is virtually no research on the instructional design aspect of strategies used in course development” (p. 36).

2.11 Theoretical Framework

This section on the theoretical framework first illustrates how an instructional development cycle model, a systematic process of instructional design, and Gagné’s Nine Events of Instruction were amalgamated to create the Combined Instructional Design and Development Model. This section then describes the learning theories that need to be applied to help ensure that the instructional strategies would lead to effective learning.

2.11.1 Combined Instructional Design and Development Model

As discussed above in this chapter, instructional development cycle models guide instructional development processes for creating materials that enhance learning. Although the ADDIE model provides the basic needs, the ADDIE model can be restrictive if a linear approach is followed. A nonlinear instructional development cycle model makes it possible to evaluate and revise the materials as they are being designed and developed (Fenrich, 2014; Parsons, 2008).

Using a nonlinear model, as shown in Figure 2.4, which was based on the ADDIE model, the instructional development cycle begins with the analysis phase and continues with the planning, design, development, and implementation phases. The

evaluation and revision phase is ongoing throughout the development cycle. The end of each phase acts as both a milestone and a checkpoint. After each phase, the outputs are evaluated and revisions are made until the team is ready to begin the next phase.

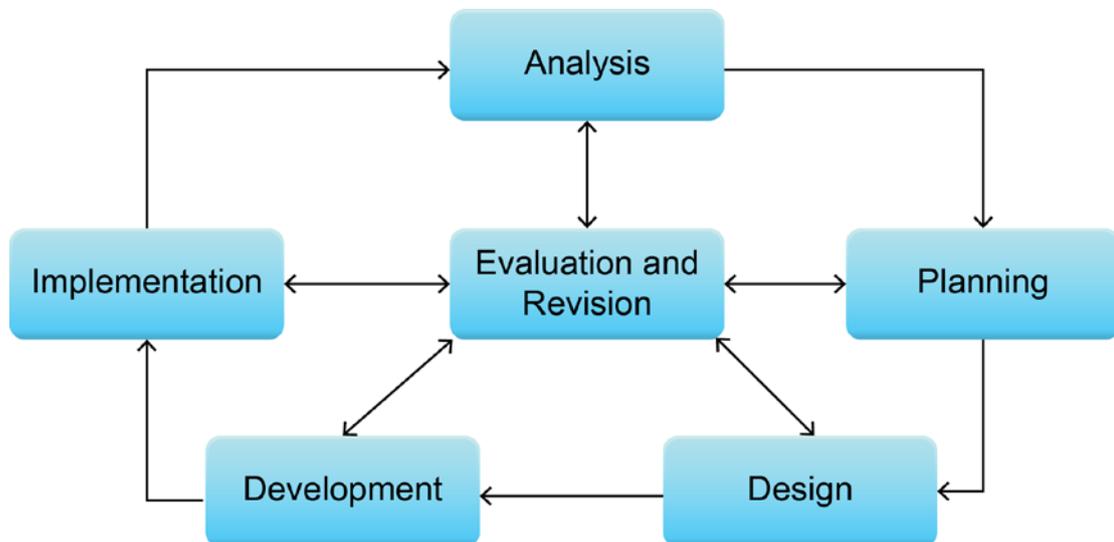


Figure 2.4 – Nonlinear Instructional Development Cycle Model

The above nonlinear instructional development cycle model does not inherently lead to effective instructional materials because it does not contain the detailed steps needed to design instructional materials. Consequently, the nonlinear instructional development cycle model needs to contain a systematic instructional design process (Fenrich, 2014). Steps of the systematic instructional design process, which were based on Dick and Carey's (1990) model, include identifying the instructional goal, conducting a goal analysis, conducting a subordinate skills analysis, identifying entry skills and characteristics, writing learning outcomes, developing criterion-referenced test questions, developing an instructional strategy, developing and selecting instructional materials, and conducting formative evaluations, with getting feedback and revising at each step. The systematic instructional design process is shown in Figure 2.5.

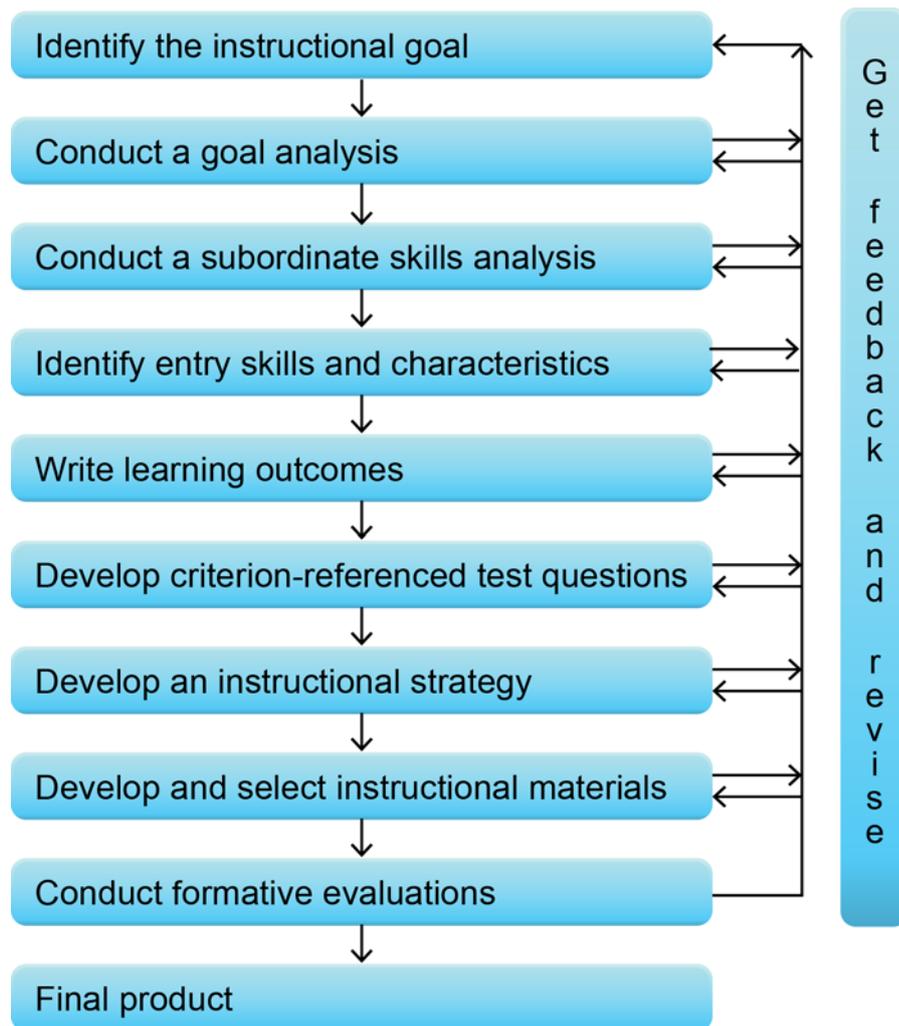


Figure 2.5 – Systematic Instructional Design Process

The systematic instructional design process does not in itself provide all of the attributes that effective instructional materials need. To help ensure effective learning, the creation of educational materials should, in general, be based on principles of instructional design and follow a model such as Gagné’s Nine Events of Instruction, as shown in Figure 2.6. Gagné’s Nine Events of Instruction are gaining attention, informing the learner of the learning outcome, stimulating recall of prerequisites, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer (Al-Hadlaq, 1994; Gagné et al., 1988; Maryannakis, 2009; Parsons, 2008; Singh, 2010).

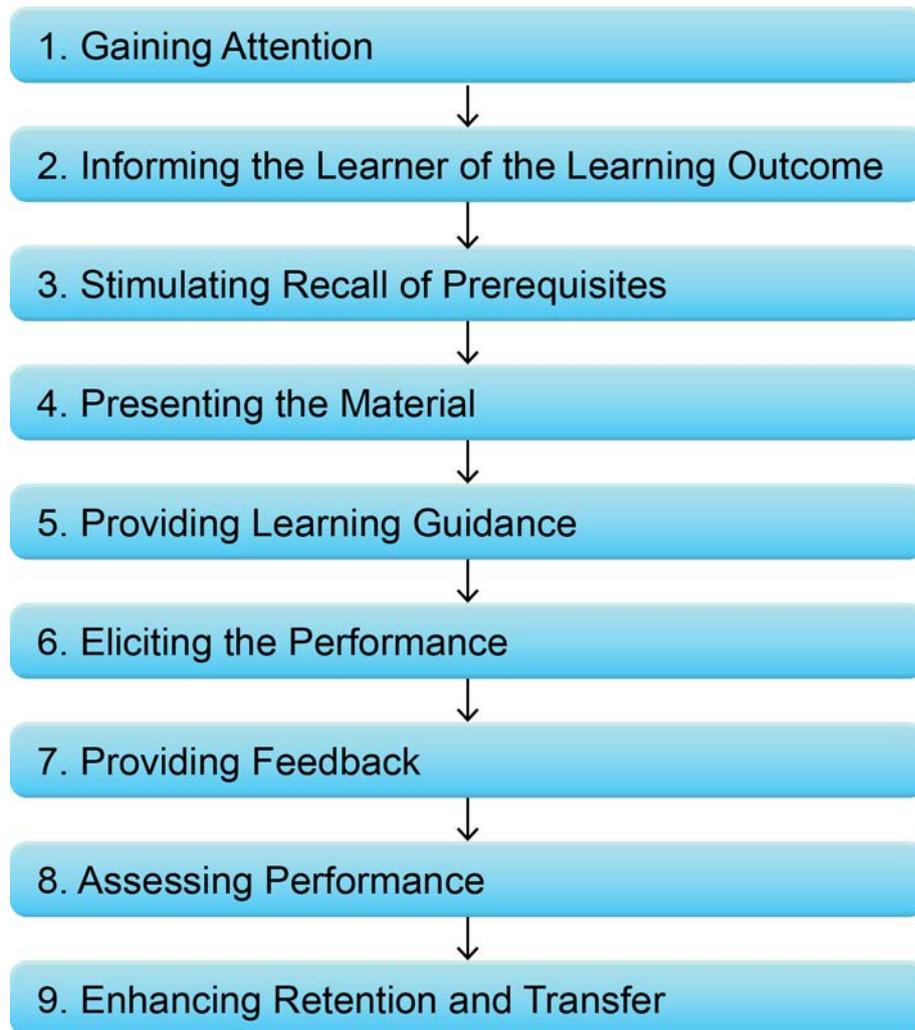


Figure 2.6 – Gagné’s Nine Events of Instruction

The non-linear instructional development cycle model was merged with the systematic instructional design process and Gagné’s Nine Events of Instruction to create a Combined Instructional Design and Development Model, as depicted in Figure 2.7. This model can be used as a foundation to create effective instructional materials.

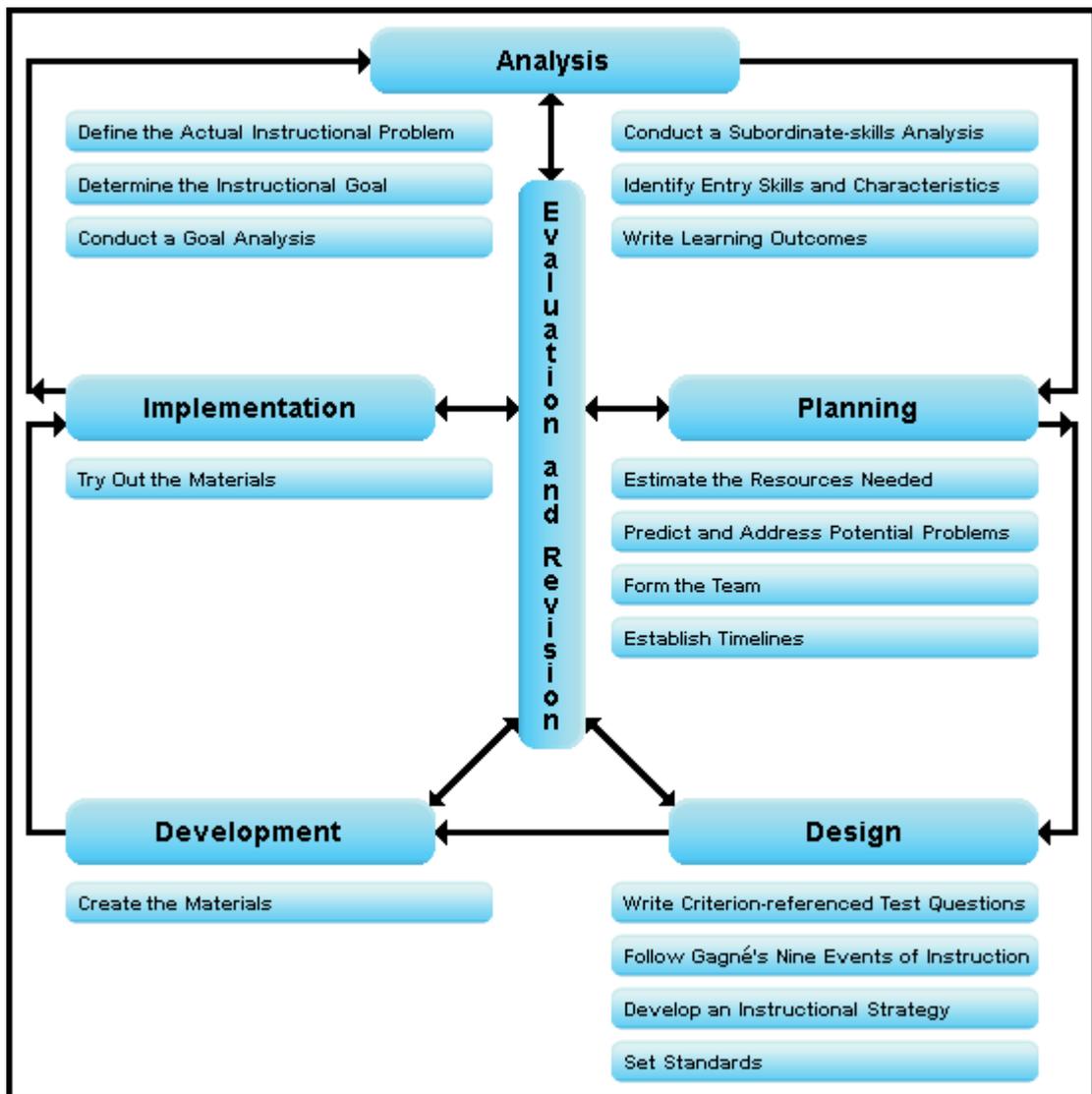


Figure 2.7 – Combined Instructional Design and Development Model

Literally following a model that contains iterative steps of evaluation and revision could lead to problems for a number of reasons. If resources are limited, it may not be possible to thoroughly complete all of the phases. If evaluations are continually done, there may always be revisions to do. In other words, the project may never end. For practical reasons, it can become too costly to keep making changes, particularly when the value gained is small. One must recognize that perfection is not worth achieving, assuming it can be achieved. For logistical reasons, some phases may need to begin before other phases are completed. This should be expected and should not cause problems as long as the needed outputs are available to start those steps of the next

phase (Fenrich, 2014). It can be argued that any model will have weaknesses depending on how it is followed and the context in which it is being used. However, the model that is followed should have strengths that add value to the project, especially if adaptations are made as is needed.

2.11.2 Creating Effective Instructional Materials

The Combined Instructional Design and Development Model provides the framework for designing effective instructional materials. Within the framework instructional strategies are needed for teaching each learning outcome. These instructional strategies need to be based on the relevant learning theories, as discussed in detail earlier in this chapter.

Following Piaget's theory of cognitive development, the highest thinking level within the content needs to be at a level that learners can achieve. Parallel to this, Vygotsky's Zone of Proximal Development theory must also be applied. If the gap between the student's current skill level and the content being taught is too high, the student will not be able to learn the content. Consequently, the skills learned must gradually build in small incremental steps from the student's current ability to the highest skill level desired for each learning outcome. However, a learner's ability will not improve if the learner does not focus on the content (Coffee, 2009; Leiker, 1993; Reddy, 2008; Stambaugh, 2007).

Within the content, important concepts must be emphasized so that the learner focuses on the material. Techniques for motivating learners need to be incorporated into the materials as this also helps learners concentrate on the content. When a learner concentrates, the learner can encode new concepts stored in short-term memory with existing concepts from long-term memory and then store that linked information in long-term memory for later retrieval. When the new concepts match an existing mental

model, the concepts are assimilated into long-term memory. When the new concepts extend an existing mental model, the concepts are accommodated into long-term memory. While factoring in the cognitive load theory, which suggests that only a manageable amount of content should be presented at a time so as to not overload the short-term memory, instructional materials need to facilitate both the assimilation and accommodation of new concepts into long-term memory. Assimilation and accommodation allow learners to construct knowledge, which is a tenet of the constructivism theory (Fenrich, 2014; Heo, 2012; Katzlberger, 2006; Robertson, 2005; Ruzhitskaya, 2012).

Also, based on the constructivism theory, the instructional strategies should provide practice opportunities with immediate and elaborative feedback to help learners construct accurate mental models of the concepts in long-term memory, be highly interactive to engage the learner, and allow learners to proceed at their own pace to enable the learners to spend the time needed to master the materials. Allowing learners to proceed at their own pace supports the important concept of metacognition, where learners monitor their progress and decide what is needed to support their learning goal (Arslan & Akin, 2014; Bessick 2008; Burkhart, 2006; Cott, 1991; Fenrich, 2014; Katzlberger, 2006).

Learning theory also suggests that the materials have variation so that each learner has some activities that he or she prefers, support the corresponding learning outcome, direct the student to learn the content deeply, guide the students in how to solve each of the skills, include questions that are at the highest appropriate thinking level, have elaborative feedback that is accurate and complete, include summaries, and deliberately aim to teach skill transfer, such as through presenting varied problems and solutions (Cott, 1991; Fenrich, 2014; Katzlberger, 2006).

2.12 Summary

The second chapter of this report, this literature review, discusses thinking skills, learning theories, instructional design, the transfer of learning, screen and interface design, assessment of thinking skills, findings on teaching higher-order thinking skills, findings for comparable interventions, research on the transfer of thinking skills, and the theoretical framework.

Although this study focuses on the specific logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning much of the research is based on broader constructs, such as higher-order thinking skills, as there is little research that addresses the narrower topic of logical-thinking skills or its subskills. Some of the broader categories of higher-order thinking skills include critical-thinking, creative thinking, divergent thinking, convergent thinking, and metacognition.

With respect to the relevant foundations of learning theory as applied to the creation of instructional materials, cognitive development is critical as one needs to know whether learners are mentally capable of learning the concepts taught. Based on Piaget's theory of cognitive development, Vygotsky's zone of proximal development theory, and findings in the literature, it was expected that the grade six and seven subjects of this study would be mentally capable of learning the logical-thinking skills taught in the interventions.

The design and development of an instructional intervention should factor in how short-term and long-term memory are used to process and store information, constructivist learning principles, practice and feedback, metacognition, and motivation. As well, the instructional design and development should be based on a nonlinear variation of the ADDIE instructional development cycle model, follow a systematic

instructional design process, apply principles of instructional design, and incorporate Gagné’s Nine Events of Instruction, while considering how higher-order thinking skills can and should be taught.

With respect to transfer of learning, gains are more likely to occur when there is a deliberate effort to teach near-transfer skills. One instructional strategy that is expected to help the transfer of learning to occur is to provide practice opportunities of the skills in different situations.

Given that the screen or page design can impact the success of educational software and paper-based materials, educational materials need to be intuitive to use, be written in language that is suitable for the learner with the text being clear, concise, to the point, and in a conversational style. Materials should be visually appealing, such as through having “white space”, minimal changes in fonts, and consistent font sizes, use of colours, and placement of page items.

The instruments typically used to assess higher-order thinking skills do not inherently measure all of the specific logical-thinking skills addressed in this research and not in the same context for the same age group. Consequently, none of the existing tools were appropriate for this study.

The literature showed that higher-order thinking skills can be taught by educational-software and paper-based teaching methods, comparable interventions that aimed to teach higher-order thinking skills should have similar findings, children and adolescents of varying ages can learn a variety of higher-order thinking skills if they have the foundational knowledge needed to learn the skills, higher-order thinking concepts learned through educational software can be transferred to other problems or situations, and the transfer of higher-order thinking skills is more likely to occur with near-transfer skills than far-transfer skills.

Overall, the literature only provided general principles of effective instructional design. The literature suggests that the theoretical framework should follow a nonlinear instructional development cycle. The cycle can include the phases of analysis, planning, design, development, and implementation, with evaluation and revision ongoing throughout the cycle, as well as a systematic process of instructional design. The systematic process of instructional design includes the steps of identifying the instructional goal, conducting a goal analysis, conducting a subordinate skills analysis, identifying entry skills and characteristics, writing learning outcomes, developing criterion-referenced test questions, developing an instructional strategy, developing and selecting instructional materials, and conducting formative evaluations, with getting feedback and revising at each step. The design phase should include Gagné's Nine Events of Instruction. These events are gaining attention, informing the learner of the learning outcome, stimulating recall of prerequisites, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer.

Chapter 3

Methodology

3.0 Introduction

This chapter presents the methodology that was used in the study. The topics discussed are research design, the population and sample, instrumentation, data collection procedures, data analysis procedures, and approvals. Within research design, the qualitative method, qualitative analysis through the Combined Instructional Design and Development Model, trustworthiness of the qualitative analysis, quantitative methods, internal validity, external validity, and the treatment are discussed. The population and sample, instrumentation, data collection procedures, and data analysis procedures topics address both the qualitative and quantitative aspects of the study.

3.1 Research Design

Given, as stated by Dawson (2006) and Rodriguez (2009), mixed-methods research design provides strengths that make up for the weaknesses of purely quantitative or qualitative design, a mixed-method research design was adopted. A qualitative assessment was conducted to ascertain the appropriateness of the materials and a quantitative assessment was done using a pre-test, post-test, experimental design to assess the effectiveness of the materials in teaching logical-thinking skills.

3.1.1 Qualitative Method

This section addresses the qualitative analysis of the research. The rationale for using a qualitative method was to ensure as much feedback as possible was received from the reviewers for designing the educational-software and paper-based resources.

According to Legant (2010), “the results of a qualitative study shed light on the context of meaning, the application of knowledge, and practical use of knowledge (Creswell, 2006)” (p. 44). While qualitative analysis can be used to completely describe an experience, it can also be used to focus on a narrow or particular aspect of interest (Legant, 2010; Yin, 2003), especially if in-depth information is valuable (Dawson, 2006; Deines, 1997; Yin, 2003). As well, Kingston (2011) suggested that a qualitative analysis can be beneficial when related research is available but little research has been done on something of specific interest. With respect to this research, there are well-established models for instructional development and principles of instructional design but little research had been done in the realm of designing instructional materials for teaching logical-thinking skills.

Specifically, to determine if the educational-software and paper-based materials had the attributes to teach logical-thinking skills, the qualitative analysis aimed to provide information on whether the materials were at a cognitive level that is suitable for grade six and seven students, the instructional strategies should effectively teach logical-thinking skills, and any changes were needed in the content itself. Each of the reviewers checked and evaluated both the paper-based and educational-software instructional materials. The qualitative information from the reviewers was gathered through semi-structured interviews and written feedback. As recommended by Allrich (2002), Andrusyszyn (1996), Bowman (2000), and Yin (2003), interviews should be used over other data gathering techniques, such as surveys, when insights, specific

information, and depth of information are needed. To gain in-depth information, interviews should be guided or semi-structured, where each interviewee is asked the same questions so that information can be compared and contrasted but also enable insights to be gleaned (Dawson, 2006; Yin, 2003).

3.1.2 Qualitative Analysis in the Instructional Development Cycle

As discussed in Chapter 2, the Combined Instructional Design and Development Model, as shown in Figure 2.7, was created to provide the foundation for creating the instructional interventions. The qualitative analysis had different activities in each phase of the Combined Instructional Design and Development Model, as discussed below.

Analysis Phase

In the analysis phase, after showing a reviewer examples of educational software to illustrate the potential and strengths of the technology, the researcher interviewed the reviewer to define the actual instructional problem, determine the instructional goal, conduct a goal analysis to depict the specific logical-thinking skills to be taught, perform a subordinate-skills analysis to determine how, if needed, the skills should be broken down into smaller elements, determine entry behaviours and characteristics, such as the target audience's expected cognitive level of development, maturity, motivation, and attention spans, and write a learning outcome for each skill identified in the goal analysis. The interview started with the statement, "Let's determine what thinking skills we should teach." After this, the interview was semi-structured with open-ended questions to freely generate ideas, as recommended by Allrich (2002), Dawson (2006), and Singh (2009). The interview generated ideas on which skills to teach, assessed the feasibility of teaching each skill given constraints of stand-alone

educational software, stand-alone paper-based materials, cost, and time. The specific results of the analysis are stated below.

The actual instructional problem was defined as grade six and seven students not having the level of logical-thinking skills needed.

The instructional goal was to teach grade six and seven students logical-thinking skills. These students were respectively eleven and twelve years old.

The goal analysis resulted in a depiction of the specific logical-thinking skills to be taught. These included the skills of classification, analogical reasoning, sequencing, patterning, deductive reasoning, and convergent thinking. This is shown in Figure 3.1. This decision factored in the limitations of what can be taught effectively given a self-paced stand-alone mode of delivery as well as what can be developed in a reasonable time frame.

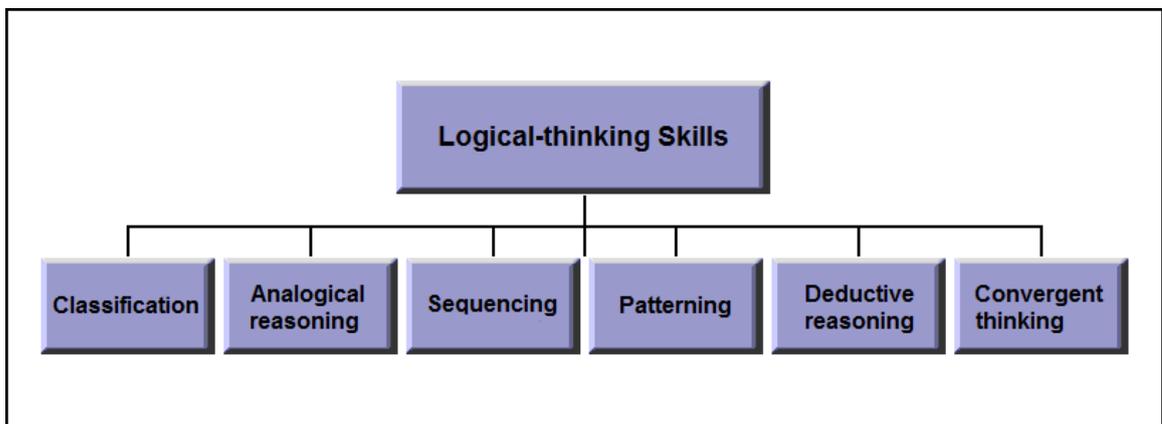


Figure 3.1 – Initial goal analysis of this study

With respect to the subordinate skills analysis, it was determined that none of the skills needed to be broken down into smaller elements.

A number of entry behaviors and characteristics were identified. The subject's cognitive development and English vocabulary needed to be at the grade six or higher level. The educational-software intervention learners needed computer literacy skills, such as being able to use a mouse. The subjects needed to be mature enough to learn from self-paced stand-alone materials. The reviewer confirmed that grade six and seven

students had these entry skills. The reviewer believed that the students would be motivated to learn the materials because of the inherent challenge of learning the skills to be taught, if the materials were highly interactive. Students were also expected to be motivated by statements in the materials such as, “See how many you get right on the first try!”

A learning outcome was written for each skill identified in the goal analysis. This clarified how the skills taught within this study differed from other studies that taught skills with the same name. For the classification skill, the learning outcome was to determine the fourth word, from a list of words, that has the same thing in common with three given words. For the analogical-reasoning skill, the learning outcome was to determine the missing word, from a list of words, of a second pair of words, based on the relationship of the first pair of words. For the sequencing skill, the learning outcome was to determine the next number in a series of numbers. However, later in the process, a reviewer suggested that the learning outcome should be to “determine the next two numbers in a series of numbers”. This change was implemented. For the patterning skill, the learning outcome was to search for patterns to find solutions. For the deductive-reasoning skill, the learning outcome was to solve matrix problems based on the given clues. For the convergent-thinking skill, the learning outcome was to determine the solution to a problem through asking questions. Based on reviewer feedback later in the process, this learning outcome was subsequently removed.

Evaluation was ongoing throughout the analysis phase. Based on the discussion, revisions were made until there was agreement on the problem definition, instructional goal, goal analysis, subordinate skills analysis, entry behaviours and characteristics, and learning outcomes.

Planning Phase

For this study, most of the planning phase work was done by the researcher. Some details were provided by the reviewers through discussions with the researcher. Within the planning phase, it was important to estimate the resources needed, predict and address potential problems, such as gaining the necessary approvals, identify costs, hardware, and software needs, form the team, and establish timelines for completing each task (Fenrich, 2014; Reddy, 2008).

Estimates for a number of resources were made. It was estimated that the time needed was approximately 500 hours for instructional design, 100 hours for the reviewers, 500 hours for computer programming for the educational-software intervention, 35 hours for graphic design, and up to 30 hours for pilot students. A PC platform computer lab for about 30 students would also be needed.

With respect to potential problems, approvals were needed from a research ethics committee, a principal (for the site of the research), the teachers of the students, the school district of the school, and parents of the subjects before the research could begin. Work towards gaining these approvals was begun. Cost was irrelevant as only photocopying was needed and the authoring tool for creating the educational software was already purchased. The researcher knew that the authoring tool could make executable files that ran on virtually any relatively recent PC-based hardware platform running the Windows® operating system. The reviewers stated that most of the schools had PC computers running Windows®. Consequently, it was expected that hardware and software would not be an issue.

The team was expected to consist of the researcher completing the instructional design based on suggestions from reviewers on how each of the skills should be taught, the researcher writing computer code to create the educational software, five reviewers

checking and evaluating the instructional strategies and content, the researcher creating images for the patterning skill, and pilot students reviewing the materials. Since the design and development would be done by the researcher and reviewers were known and had made a commitment to supporting the research, there was no concern with respect to team members.

The instructional design, including review and evaluation by the reviewers, was expected to be completed in about nine months. Similarly, the computer programming was estimated to be completed in about nine months. Graphics were anticipated to take about a week to complete. The pilot-student review was planned to be completed over approximately one month. The research itself was expected to require about two months to complete.

With respect to evaluation and revision, little was done in this phase as only confirmation of the details was needed.

Design Phase

In each of the following tasks of the design phase, the instructional designer worked closely with reviewers.

Criterion-referenced pre-test and post-test questions were written by the researcher for each of the learning outcomes. The test questions for the classification, analogical reasoning, and sequencing skills were written to be comparable to the level assessed by official exams of the Canadian government for grade six and seven students. Since the patterning and deductive-reasoning skills were not assessed through these exams, the researcher interviewed a reviewer to determine the level these skills should be assessed, given the expected level of cognitive development of the target audience. After the criterion-referenced pre-test and post-test questions were written, the reviewers assessed the questions to ensure that the questions were appropriate for the

target-audience students, the questions accurately assessed each learning outcome, each pre-test was equivalent to the post-test, the questions on the pre-tests and post-tests paralleled but did not duplicate the questions in the instructional materials, the answer to each question was correct, the incorrect answers to each question had a reason to be believable, and the target-audience students would be able to answer the questions. Upon reviewing the resulting questions and seeing that their suggestions were incorporated into the questions, the reviewers felt that the test questions met the above criteria.

A decision was made to use multiple-choice questions for the classification, analogical-reasoning, sequencing, and patterning skills because multiple-choice questions are easy to mark using educational-software, short-answer questions, a possible alternative for the interventions, are difficult to mark accurately on computers given things like spelling, capital letters, keyboarding skills, typos, and blank spaces need to be addressed within the answer judging (Fenrich, 2014), learners sometimes have difficulties when taught using one method (i.e., through using multiple-choice questions as was needed for the educational-software intervention) and then being formally assessed with a different method, such as fill-in-the-blank questions (Fenrich, 2014), multiple-choice questions can be marked entirely objectively (Fenrich, 2014), and the educational-software and paper-based interventions needed to parallel each other as closely as possible (Clark, 1983).

To reduce the guessing factor on the multiple-choice questions, there were five answer choices and each alternative was plausible, grammatically correct with the stem, and similar in length. To make the answers plausible for the classification and analogical-reasoning skills, each answer choice had an association with the given words. This was done because, if an individual does not know the relationship that

connected the given words to the correct answer, he or she will tend to select any word that he or she feels has an association with the given words (Moran, 1989). Similarly, there was a rationale for each alternative answer for the sequencing skill questions. For example, the rationale was sometimes based on a possible mathematical error. As well, classification and analogical-reasoning skill answers were placed in alphabetic order and sequencing skill answers were placed in numeric order to eliminate any pattern for correct answers. For the patterning skill, there were one to three correct answers out of five choices for each question, which minimized the chance of a subject guessing answers.

With respect to the instructional strategies used to present the material for each learning outcome, the researcher interviewed reviewers to determine general principles of how they taught logical-thinking skills. The researcher combined the presented ideas with the researcher's own knowledge and experience in creating instructional materials to design the instructional strategies for the learning outcomes. The instructional design is discussed in detail below within Gagné's Nine Events of Instruction.

The media needed to support the instructional strategy consisted of images for the menus, introductory pages, and patterning skill. No video or audio was required for subjects to learn the skills. Since the images needed for the menus were beyond the capabilities of the researcher to create, a graphic artist was added to the team.

The standards and look and feel were defined. Both the educational software and paper-based materials were designed to be intuitive to use and allowed the student to proceed as desired, such as being able to review as needed. The writing was in the second-person voice and was pragmatic in nature, as was deemed to be fitting by the reviewers for students in grade six and seven. The language was appropriate for the learners. The text was clear, concise, to the point, and in a conversational style. Both the

educational software and paper-based materials were designed to be visually appealing, through having “white space” so that the screen or page does not feel crowded, minimal changes in fonts to help give a professional appearance, consistent font sizes for the different screen or page components to help prevent confusion, consistency in the placement of orientation information, instructions, text content, images, and feedback, and consistent use of colours for the educational software. Due to cost constraints, the paper-based materials were printed in black and white. The menus were designed to be easy to follow. An example of a paper-based intervention menu is shown in Figure 3.2 and an educational-software intervention menu is shown in Figure 3.3. Figures 3.4 and 3.5 respectively show a sample page design from the paper-based and educational-software interventions. The page design illustrates the orientation information, text locations, prompt locations, prompt wording, navigation, fonts, and colours. With respect to scoring in the self-test, an example of feedback in the paper-based intervention is:

“If you scored 8 or less out of 10:
You have completed this ‘Self-test’. You should repeat the ‘Samples’ and ‘Activity’ and then try this ‘Self-test’ again.

If you scored 9 or higher:
You have successfully completed this logical thinking exercise! You are done but consider trying the ‘Challenge for Experts’.”

For the educational-software intervention, an example of feedback based on the subject scoring less than nine out of ten is:

“You have completed this ‘Self-test’. You should repeat the ‘Samples’ and ‘Activity’ and then try this ‘Self-test’ again.”

whereas the feedback for a score of nine or ten out of ten is:

“You have successfully completed this logical thinking exercise! You are done but consider trying the ‘Challenge for Experts’.”

Contents	
1. Samples, page 1	
2. Activity, page 22	
3. Summary, page 53	
4. Self-test, page 54	
5. Challenge for Experts, page 74	

Figure 3.2 – Sample menu from the paper-based intervention



Figure 3.3 – Sample menu from the educational-software intervention

16

1. One For All and All For One

Sample 4 – Step 2

Given: push ram thrust

a. boost b. energy c. force d. pull e. shove

Step 1: Determine what is common between the three given words.

They all have a similar meaning.

Step 2: From the answer choices, find a word that has a similar meaning.

Turn the page when you have thought of the word.

Figure 3.4 – Sample page design from the paper-based intervention

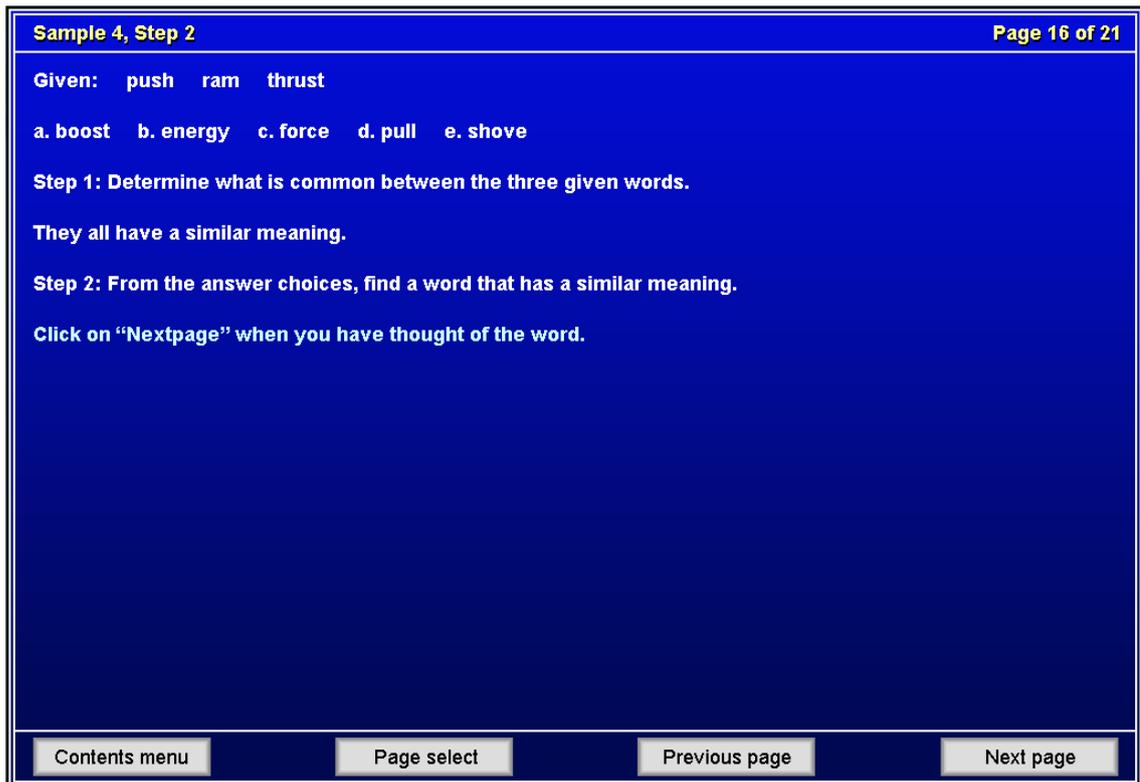


Figure 3.5 – Sample page design from the educational-software intervention

Table 3.1

Differences Between the Paper-based and Educational-software Interventions

Paper-based Intervention	Educational-software Intervention
The menu page listed page numbers with each menu item so that a learner could easily find each section.	The menu page did not list page numbers. Clicking on any menu item immediately branched a learner to that section.
If subjects wanted to view a specific section or page, the subject had to spend time to manually find it.	If subjects wanted to branch to a specific section or screen, the subject could click buttons to quickly branch there.
Black and white due to the extra cost of printing thousands of pages in colour. Correct answers were highlighted in bold.	Yellow orientation information, white text, light blue prompts, correct answer feedback in yellow, incorrect answer feedback in magenta, and blue background. Correct answers were highlighted with a box.
Subjects manually flipped to the next page to see more content.	Subjects clicked on a button to move to the next screen to see more content.

Table 3.1, continued

<p>Subjects read further down the page or the next page for successive hints. Subjects were told to not read the hints until the hints were needed. The hints were either separated by white space or on a subsequent page so that it was a deliberate choice to read them.</p>	<p>A subject was automatically provided with a hint if he or she answered a question incorrectly. A subsequent hint was provided if another mistake was made.</p>
<p>Subjects manually flipped to the next page to see a correct answer. They compared their answer to the provided answer.</p>	<p>Subjects received instant feedback on the same screen when they selected an answer.</p>
<p>For the main learning activity and self-test, subjects had to count their own scores and determine what they should do based on the statement provided.</p>	<p>For the main learning activity and self-test, the software recorded and displayed scores and provided specific advice based on a score.</p>
<p>Learners were challenged to see how many questions they could answer correctly on the first try but had to keep track of their own score.</p>	<p>Learners were challenged to see how many questions they could answer correctly on the first try. The software prompted with words like, “Correct on first try: 12 of 15”.</p>
<p>For the deductive-reasoning skill, the learners had to manually compare their work to a series of matrices that gradually showed the solution. If a learner made a mistake, they would have to erase some of their work and try again.</p>	<p>For the deductive-reasoning skill, the learners received instant feedback about whether an answer was possible to know based on the information in the matrix. The learner clicked “Try again” to remove his or her last input.</p>

Note that there are some differences between the interventions based on their own limitations or costs, as listed in Table 3.1. The reviewers did not believe that these differences would create a significant difference between the two experimental groups.

For the educational-software intervention, the programming of templates and sub-routines was not started since the researcher needed to first complete the instructional design. However, through communication with and evaluations by a reviewer, it was established that, with minor changes, the screen and user-interface designs that the researcher used on previous projects would be effective for the grade six and seven subjects of the study. Although the past designs were a part of award-winning educational-software solutions, the designs had never been used with subjects

as young as those of this study. A reviewer suggested that “the menus should have cartoon images”.

The site for the research was tentatively confirmed. Acceptance depended on a letter from a research ethics committee, which was in progress.

An evaluation was conducted and revisions were made as needed.

Development phase

The paper-based intervention was created based on the instructional strategies and design specifications produced in the design phase. Each page of the paper-based content became the foundation for each screen of the educational-software intervention.

In the development phase, each reviewer provided suggestions for any changes needed with respect to whether the instructional materials were suitable and effective for academically weak through strong students, answers to questions in the instructional materials were correct, incorrect answers to each question had a reason that a learner might select it, the feedback to each question was correct and comprehensive, the screen design and user-interface were effective for the educational-software intervention, and text was clear and free of mistakes, such as spelling and grammatical errors (Dunning, 2008; Fenrich, 2014; Reddy, 2008; Singh, 2010).

Each suggestion and its rationale was analyzed with respect to instructional effectiveness before a change was made. Allrich (2002) and Hugo (1989) stated that being analytic is an important aspect of qualitative research.

Dawson (2006) and Yin (2003) recommended that to determine potential problems in the use of a technology, the researcher should directly observe individuals using the educational software to determine whether or not the software was easy and intuitive to use. This was done by the researcher, who observed four of the reviewers.

Based on written feedback on the reviews by the reviewers and discussions to ensure understanding as needed, the following was done for this study.

There were no changes in the media specifications. The media was developed as planned.

Formative evaluations were conducted on the paper-based materials. The iterations of evaluation and revision were done sequentially from the researcher initially reviewing the materials he had created, written feedback by one reviewer, and then written feedback from the other five reviewers. (At this time a sixth reviewer also volunteered to review and provide feedback on all of the content.) One reviewer first reviewed the materials and those changes were implemented to save time in that the other reviewers did not have to spend time repeating the same feedback as the first reviewer. The written feedback provided by the reviewers was clarified as needed through discussions. As a result of the feedback, the instructional materials evolved throughout the process.

Once the paper-based content was finalized, the educational-software version was started. Adaptations were made to utilize the strengths of the computer technology. The educational software was created section-by-section with an iterative cycle of formative feedback and revisions.

Approximately six months before the study was to commence, a prototype of the software was tested on a computer within the school in which the study would take place. The software ran without any problem.

Once both the paper-based and educational-software interventions were fully reviewed and revised based on feedback from the reviewers, pilot students worked through all of the materials. Each pilot student proceeded through every page or screen of the paper-based or educational-software intervention that he or she received and

noted any spelling or grammatical error, text that did not make sense or could be written more clearly, disagreement with an answer, problems in the user-interface of the educational software, and the time needed to complete each lesson. The qualitative information provided by the pilot students was analyzed with respect to instructional effectiveness before a change was made.

Based on their performance and feedback, modifications were made. The performance scores of the pilot students were low on the patterning skill and high on the deductive-reasoning skill. For the patterning skill, a reviewer said, “More samples and more questions and feedback are needed.” For the deductive-reasoning skill, a reviewer stated, “The problems could contain more complex relationships, such as one being greater than another.” Extra content was created for all of the corresponding sections of the intervention (e.g., samples, activity questions, summaries, self-test, challenge questions, pre-tests, and post-tests). These additions were then evaluated by the reviewers.

Implementation Phase

For this study, in regards to the implementation phase, the following was done by the researcher:

About a month before the formal research was to begin, the software was loaded onto a typical computer in the school that the study was to take place. Once it was known that the software ran as expected, the software was then loaded onto the school’s computer network by the technical support staff of the school district. Once that was done, the software was tested on each computer in the lab. This test entailed working through every page and question of each logical-thinking skill lesson. The software again ran as expected. No changes were needed. The interventions were ready to be implemented.

In this phase, the materials were not tested with sample students in the school's computer lab because those students would be a part of the study and pilot students had already tested the materials.

Evaluation and Revision Phase

For this study, as described above, formative evaluation was conducted during each phase of the Combined Instructional Design and Development Model. Revisions were made as needed. The resulting instructional materials emerged from the information provided through the qualitative analysis. This report also presents the results of the formal summative evaluation that was conducted.

3.1.3 Qualitative Analysis in Gagné's Nine Events of Instruction

With respect to this study, given that teachers often do not follow a specific instructional model when designing instructional materials (Hart, 2008), the researcher designed the materials following Gagné's Nine Events of Instruction, as described in Chapter 2 and is shown in Figure 2.6, as it was a solid foundation from which to design the instructional strategies (Al-Hadlaq, 1994; Gagné et al., 1988; Maryannakis, 2009; Parsons, 2008; Singh, 2010).

Gaining attention

In this study, the techniques used to gain and maintain attention were based on the reviewers' recommendations to "ask the students to obtain high scores", "stress the importance of thinking carefully", "make the materials highly interactive", and "pose challenging statements and questions". These techniques also supported the need to keep students motivated. Sample statements were:

- "See how many you get right on the first try!"

- “Note that you will be better able to complete the ‘Activity’ if you take time to understand the logic used in these samples.”
- “Think about 2 things that can now be filled into the matrix.”
- First page of a sample: “What is the pattern of how the numbers change?”
“Turn the page to check your answer.”
- Second page of a sample: “Pattern: Alternating between adding 2 and adding 1.”
“What are the next two numbers?”
“Turn the page to check your answer.”

Informing the learner of the learning outcome

A reviewer helped determine each learning outcome. The learning outcomes were written to be clear, measureable, and at the highest appropriate level of difficulty (Al-Hadlaq, 1994; Fenrich, 2014; Singh, 2010). The learner was informed of each learning outcome. However, for the deductive-reasoning skill, the learning outcome was phrased as “use clues to find solutions” rather than the actual learning outcome that was to “solve matrix problems”. This was done in case the learner did not know what a matrix was.

The convergent-thinking skill learning outcome was removed from the list of learning outcomes to be covered. The reasons are discussed in the “Presenting the material” event below.

Stimulating recall of prerequisites

In this study, recalling prerequisites was not needed as a part of the instructional strategy. The skills were taught from a foundational level that was suitable for grade six and seven students. It would not have been helpful to mention the required entry skills, such as their English vocabulary needed to be at the grade six or higher level. Variability with respect to following Gagné’s Nine Events of Instruction is acceptable. According to Singh (2010), “All nine events do not have to be included by the

instructional designer simultaneously or in sequence. The inclusion of an event and its sequence depends on the objective, the audience and instructional content (Gagné et al., 1988)” (p. 66). Similarly, Hart (2008) stated that “successful instructional designs must be, to some extent, situation-specific” (p. 157).

Presenting the material

With respect to presenting the material, there were a number of instructional features in each of the lessons created for this study. Some of these features were based on the reviewers’ recommendations for teaching logical-thinking skills, which included that it was important to “ask numerous questions”, “stimulate a high level of thinking”, and “gradually increase the difficulty of the content”.

To support academically weak through strong target-audience students, the materials were designed for the expected level of cognitive development of students in grade six and seven. The reviewers deemed that the students could remain focused on a lesson for up to an hour, if the material was interactive. All of the activities for each logical-thinking skill were designed to be completed within one hour. This also matched the time available for students to participate in the intervention. The content would not necessarily work for younger subjects as they may not be at a high enough level of cognitive development or have the maturity to work through the large amount of material, in particular to read the detailed feedback, which was essential for supporting effective learning. In contrast, the materials may be too easy for grade eight and older students as they would, on average, have higher levels of vocabulary, better math skills, and better overall logical-thinking skills.

The concepts gradually increased in difficulty and each sample of each skill was explained in a series of manageable steps, as this fits with Vygotsky’s Zone of Proximal Development learning theory. For example, in the classification skill, the relationships

in the samples gradually increased in complexity. Sequentially, relationships were parts of a hand, examples of clothing, items worn on the upper body, words having similar meanings, and ways to lose one's balance. For the analogical-reasoning skill, the relationships in sequence were opposites, similar types of things, something that is kept in, put in, or strikes something else, something that performs in something else, things connecting to each other, what something is made of, what something uses, one has many of another, size differences, one is without equal compared to the other, one is a portion of the other, one can put out the other, and one works with the other. For the sequencing skill, the samples had sequences of numbers increasing by five, numbers increasing by one more than the last, numbers decreasing by one more than the last, every second number starting from the first number increasing by two while every second number starting from the second number increasing by one, each number multiplied by three, and every second number starting from the first number decreasing by six while every second number starting from the second number is multiplied by three. For the patterning skill, in the activity regarding facial characteristics, the patterns to discover were faces with three eyes, open mouths, a round nose and hair in two places, a solidly-coloured nose and an open smile, and hair in one place and one open eye. For the deductive-reasoning skill, the matrices increased in difficulty due to the size and number of grids. In sequence, the size of the grids were three-by-three, four-by-four, two three-by-three, and two four-by-four. After this more complex relationships in the clues were added, such as earlier than, later than, more than, less than, four more than, and four fewer than.

A variety of instructional activities and strategies were provided. Each logical-thinking skill was taught through presenting samples, practice questions, a summary, a self-test, and challenge questions. In particular, the samples, practice questions, and

summary were inherently different and thus there were varied activities. As well, each of the five logical-thinking skills required a different instructional strategy.

The activities were specifically designed to support each learning outcome. At this point, the convergent-thinking skill learning outcome was deleted. Although the skill can be taught effectively by traditional teaching methods, it was determined that it would not be possible to provide the interactions needed to invoke deep thinking because the fixed questions and responses required would restrict thinking too much, and it was thought that the number of alternatives based on the questions selected would become too unwieldy in a paper-based intervention. Consequently, the goal analysis was revised, as shown in Figure 3.6.

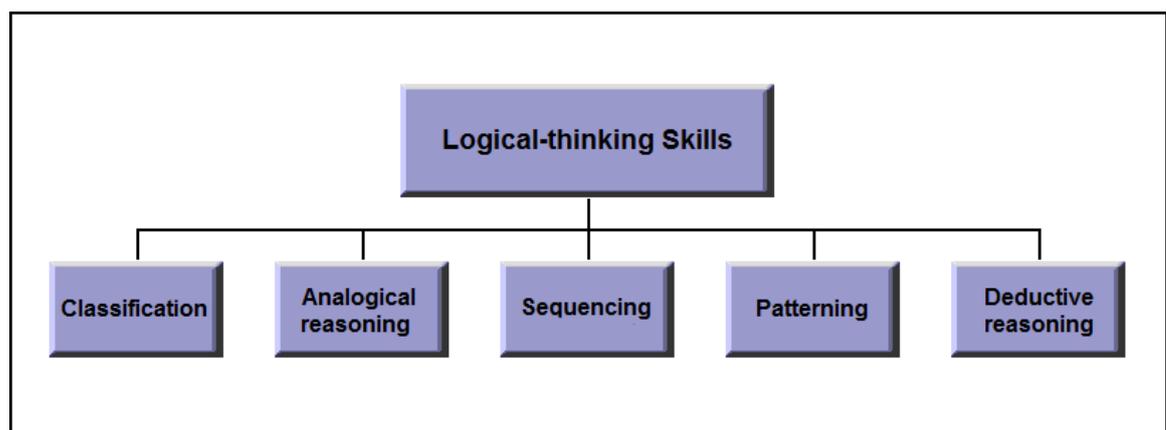


Figure 3.6 – Final goal analysis of this study

There was a high degree of active learning in the samples, practice questions, self-test, and challenge questions. Learners were highly engaged in each of these activities, especially since answering the questions required high-order thinking. Active learning is foundational to the constructivist theory of learning. The samples provided for each of the logical-thinking skills required the learners to think about each step, rather than the learners simply being told how to solve the problems. For example, in the samples for the classification skill:

On the first page of each sample, the learners were given:
“Step 1: Determine what is common between the three given words.
Turn the page when you have thought of what they have in common.”

On the second page of a sample, the learners were given:
“All are a part of a hand.

Step 2: From the answer choices, find a word that has the same thing in common.

Turn the page when you have thought of the word.”

In all of the practice questions for each skill, the learners were engaged through trying to determine each answer. After a learner initially answered a question incorrectly, rather than immediately providing the answer, which would limit thinking, hints were given that further stimulated thinking. Each hint provided information to think about and directed the learner to apply that information to reach a solution. One or more successive hints were provided that gave yet more clues towards answering the question. This elaborative feedback was correct and complete.

The learner’s focus was directed to the deeper learning concepts that supported higher-order thinking skills. As described above, this was accomplished through presenting the learner with numerous questions and ideas to consider that directly related to the higher-order thinking skill that was being taught.

The assimilation and accommodation of knowledge into long-term memory was supported. Assimilation was supported by having concepts learned in the sample problems directly relate to concepts addressed in the practice questions. Accommodation was supported by presenting new relationships in problems within the practice questions.

Principles of the constructivism theory were followed. Some examples include supporting assimilation and accommodation, the high degree of active learning, the practice and feedback provided, and learning through self-paced materials.

Metacognition and self-reflection were encouraged. There were a number of statements supporting metacognition and self-reflection. For example:

“Choose any section. However, note that you can learn the skill faster if you proceed in sequence. You can try each of these as often as you wish.”

“Note that you will be better able to complete the ‘Activity’ if you take time to understand the logic used in these samples.”

“You have completed this ‘Activity’! If you understand how to do these questions, read the ‘Summary’. Otherwise, work through the ‘Samples’ and ‘Activity’ again.”

During a review, a reviewer thought that the sequencing skill should be made more difficult based on the expected cognitive ability of grade six and seven students and suggested that the learning outcome should be changed to “determine the next two numbers in a series of numbers”. This change was done and that led to corresponding revisions to the entire intervention (e.g., instructions, samples, questions, feedback, summary, test, etc.).

Providing learning guidance

In the materials of this study, guidance for how to solve each of the skills was provided through presenting the initial samples (as described above), stating what needed to be done, and providing increasingly informative hints. The guidance was designed to help the student store the concepts in his or her long-term memory.

Guidance was provided through directly stating what needed to be done to answer the questions. This was stated in the introduction to the samples, introduction to the practice questions, and summary.

The following was provided to learners to help them solve classification questions:

“To solve ‘One For All and All For One’ [classification skills] questions:

Step 1: Determine what is common between the three given words.

Step 2: From the answer choices, find a word that has the same thing in common.

If more than one word has the same thing in common, repeat step 1.

The fourth word will match for one of many possible reasons. For example, the words could have similar meanings (synonyms), be parts of the same object, or be examples of something.”

For solving analogical-reasoning questions, the following was provided to learners:

“To solve ‘What’s Missing?’ [analogical-reasoning skills] questions:
Step 1: Determine the relationship between the first pair of words.
Step 2: Create a sentence with the first pair of words.
Step 3: Create a similar sentence using the first word of the second pair.
Step 4: Use that sentence to see which word in the list fits best.

The pairs of words will match for one of many possible reasons. For example, the words could be opposites or similar things. As well, word pairs could relate to where things are kept, what things hit other things, physical connections, parts of a whole, tools used, amounts of things, sizes, and so on.”

The following was presented to learners to support them in solving sequencing questions:

“To find the next number of a series of numbers, you need to look for a pattern of how the entire series changes. The next numbers follow that pattern. Although it is uncommon, there may be more than one way to determine a pattern.

There are many possible patterns. Some of these include:

- Add regularly increasing amounts to get the next number.
This could be +4, then +5, then +6, and then +7.
- Subtract regularly decreasing amounts to get the next number.
One pattern could be –10, then –8, then –6, and then –4.
- Add different amounts to alternating numbers.
For example, +2, then +4, then +2, and then +4.
- Subtract different amounts from alternating numbers.
This could be –3, then –5, then –3, and then –5.
- Alternate between adding and subtracting.
One such pattern could be +4, then –2, then +4, and then –2.
- Alternate between multiplying and adding.
For example, $\times 3$, then +4, then $\times 3$, and then +4.”

For solving patterning-skills questions, the learners were given the following information:

“To find matching faces, letters, numbers, or fractions, you need to use logic and look for characteristics in the third series that match the first series but not the second series.

There are many possible common characteristics. A few characteristics are listed below:

In faces, look for the number of eyes, whether the eyes are open or not, the shape of a nose, whether the nose is solidly coloured or not, the shape of a mouth and whether it is open or closed, and whether there is hair and how much hair.

In letters, check the shapes within a letter, the pieces needed to form the letters, whether there is an enclosed space, whether the letter can be evenly split in half, whether the letter has an opening and to which direction the opening opens, and their sound.

In numbers, look for the presence and position of a specific digit, prime numbers, the sum of the digits, whether it can be evenly divided, multiplication, and whether it is odd or even.

In fractions, check for the same things as with numbers. However, do this in both the numerator and denominator.”

The following was provided to learners for solving deductive-reasoning questions:

“To solve ‘Clues’ [deductive-reasoning] questions:

- Read and understand the question.
- Each question gives you initial clues. Based on each clue, place a ‘Yes’, for ‘Yes, it says so’, or ‘No’, for ‘No, it says it isn’t’, into the matrix.
- Based on what you have in the matrix, use logic to make one or more conclusions. An example of using logic is that wherever there is a ‘Yes’, every other box in that column and row must contain a ‘No’. As well, whenever all but one box of a column or row contains a ‘No’, the remaining box must be a ‘Yes’.
- Repeat this until the matrix is filled.
- The filled matrix contains the information needed to answer the questions.”

To help the learners acquire the concepts, a portion of the guidance was provided through the hints. The following is an example of hints provided when the classification skill was taught:

“Hint 1:

Step 1: Determine what is common between the three given words.

Step 2: From the answer choices, find a word that has the same thing in common.

If more than one word has the same thing in common, repeat step 1.”

“Hint 2:

Each given word is a part of a building. From the choices, find a word that is also a part of a building.”

The following example shows hints that were given while teaching the analogical-reasoning skill:

“Hint 1:

- Determine the relationship between the first pair of words.
- Use the relationship to create a sentence with those two words.
- Use that idea to find the missing word.”

“Hint 2:

The relationship is that one helps the other. A sentence could be: A hygienist works with a dentist. Try this:

- Create a similar sentence using the first word of the second pair.
- Use that sentence to find the missing word.”

The following is one example of the hints given when the sequencing skill was taught:

“Hint 1:

Look for a 2-part pattern of how the numbers change. It may help you to write down how each pair of numbers change.”

“Hint 2:

3 is subtracted and then the number is multiplied by 3.”

“Hint 3:

The series of numbers is made by subtracting 3, then multiplying by 3, then subtracting 3, and then multiplying by 3. Continue this pattern by subtracting 3 from 18 and multiplying by 3 after that.”

The following is an example of hints presented to the learner while teaching the patterning skill:

“Hint 1:

Look for one thing common to all skorks that non-skorks do not have. Consider the hair, eyes, nose, and mouth.”

“Hint 2:

Look at the mouths.”

“Hint 3:

Check whether each skork’s mouth is open or closed. Compare this to non-skorks. Three of the faces in the last row are skorks.”

The following example shows the hints provided while teaching the deductive-reasoning skill:

“Hint 1:

	Basketball	Football	Hockey	Rugby
Dennis				
Joey				Yes
Margaret			No	
Ruff	No		No	

Each ‘Yes’ and ‘No’ in the matrix is based on the given clues.”

“Hint 2

	Basketball	Football	Hockey	Rugby
Dennis				No
Joey	No	No	No	Yes
Margaret			No	No
Ruff	No		No	No

Based on hint 1:

- Since Joey likes rugby, he does NOT like basketball, football, or hockey.
- Since Joey likes rugby, Dennis, Margaret, and Ruff do NOT like rugby.”

“Hint 3

	Basketball	Football	Hockey	Rugby
Dennis			Yes	No
Joey	No	No	No	Yes
Margaret			No	No
Ruff	No	Yes	No	No

Based on hint 2:

- Since Joey, Margaret, and Ruff do NOT like hockey, Dennis must like hockey.
- Since Ruff does NOT like basketball, hockey, or rugby, he must like football.”

“Hint 4

	Basketball	Football	Hockey	Rugby
Dennis	No	No	Yes	No
Joey	No	No	No	Yes
Margaret		No	No	No
Ruff	No	Yes	No	No

Based on hint 3:

- Since Dennis likes hockey, he does NOT like basketball or football.
- Since Ruff likes football, Margaret does NOT like football.”

Eliciting the performance and Providing feedback

As with all of the events, the content created for this event was modified with suggestions of the reviewers.

In the materials created for this research, subjects were given numerous questions throughout the materials to practice the concepts at the highest needed thinking level. For each question, feedback in the form of hints of increasing detail was given, as described above. As well, for both correct and incorrect answers of the practice, self-test, and challenge questions, elaborative feedback was provided that detailed what the right answer was, why the answer was right, and why the other answers were incorrect, as was appropriate. Feedback was provided for correct answers in case the learner guessed the right answer or got it right for the wrong reasons. The following examples illustrate the elaborative feedback provided for teaching each logical-thinking skill.

Classification skill:

“Solution:

Given: runners shoes socks
a. **boots** b. feet c. footwear d. run e. walk

Boots and each given word are something specific that you can put on your feet. Footwear is not the best answer because, unlike the given words, it is a general term.”

Analogical-reasoning skill:

“Solution:

Given:

fire \rightarrow water : lamp \rightarrow _____

The word that fits best is highlighted below:

dark flame light shade **switch**

The relationship is that one can put out the other. So, use a sentence such as:
A lamp can be turned off with a _____. The word that fits best is ‘switch’.
Note that the sentences do not have to be exact. ‘Turned off’ is like ‘put out’.”

Sequencing skill:

“Solution:

Given: 30 20 40 30 60
 -10 x2 -10 x2

The next two numbers in the series are

a. **50 and 100** b. 65 and 130 c. 90 and 180 d. 120 and 110 e. 120 and 240

The pattern has 2 parts. 10 is subtracted and then the number is multiplied by 2.
The next number is 50 because $60 - 10 = 50$.
The number after that is 100 because $50 \times 2 = 100$.”

Patterning skill:

“Solution:

The following are flups:

H M N V X

The following are NOT flups:

A D G L U

The flups are highlighted below:

B **K** T **Y** Z

Flups have an opening on top AND only straight pieces.”

Deductive-reasoning skill:

“Solution:

	Crescent	Eagle	Maple leaf	Cross		Black	Blue	Red	Yellow
Albania	No	Yes	No	No		Yes	No	No	No
Canada	No	No	Yes	No		No	No	Yes	No
Finland	No	No	No	Yes		No	Yes	No	No
Malaysia	Yes	No	No	No		No	No	No	Yes

Country	Flag Symbol	Colour of Symbol
Albania	Eagle	Black
Canada	Maple leaf	Red
Finland	Cross	Blue
Malaysia	Crescent	Yellow

The self-test questions were criterion-referenced and paralleled but did not duplicate the practice questions.

In the initial version of the materials, students received a recommendation to proceed to the challenge activity if he or she made two or less mistakes in a self-test. If a learner had more than two mistakes, he or she was advised to review the samples and try the practice questions again. However, a reviewer stated, “A student should only receive a recommendation to proceed in the lesson if he or she scores a perfect mark or only makes one mistake on the self-test.” The rationale was that higher expectations tend to lead to increased learning. This change was implemented. Another suggestion of a reviewer was that “the pattern of how the numbers change should be shown directly below the sequence of numbers”. This feedback was added and is illustrated above in the sequencing skills example within this “Eliciting the performance and Providing feedback” event.

Assessing performance

In this report, a formal assessment was done for each logical-thinking skill.

Enhancing retention and transfer

For each of the logical-thinking skills of the instructional materials for the interventions of this study, retention was reinforced with a summary that reiterated the strategy of how to solve the logical-thinking skill. Transfer was specifically supported through aiming for near-transfer skills, giving challenge questions that presented content that went beyond what was covered in the “regular” parts of the material, and providing a number of ways to learn and practice the skills, such as through the guided practice, numerous practice questions, summaries, and practice tests. As well, transfer was supported when the steps for completing each skill were presented in that the text stated that the solution can be based on many reasons, which implies that the principles apply broadly. Sample statements that supported the retention and transfer of skills are listed above within the “Providing Learning Guidance” topic.

3.1.4 Trustworthiness of the Qualitative Analysis

Ennis (2006) stated that valid research of any form must enable external individuals to judge the consistency of what was done and whether the findings were neutral. Allrich (2002), Shenton (2004), and Yin (2003) refer to validity of qualitative analysis as trustworthiness that has the characteristics of credibility, transferability, dependability, and confirmability. The inherent problem in achieving trustworthiness is that all researchers have biases, tendencies, and characteristics that can subjectively influence the findings (Ennis, 2006). So, to ensure trustworthiness, the researcher must provide detailed information to portray what transpired (Hugo, 1989).

Credibility

The central tenet of credibility is whether the findings are congruent with reality (Hugo, 1989; Shenton, 2004). An important method for showing credibility in qualitative analysis is triangulation (Deines, 1997; Hughes, 2009; Shenton, 2004).

With respect to this research, triangulation resulted from obtaining the opinions and feedback of reviewers and pilot students with diverse characteristics, as discussed below in the topic entitled “3.2 Population and Sample”. The selection of these reviewers was purposeful to gain rich and varied feedback. This mix of skills and experience is consistent with the recommendation of Parsons (2008) who stated that individuals participating in a qualitative study should include experts with specialties, individuals with relevant experience in the field, and people who would be directly affected by the outcome. In this situation, the resulting materials could be used to teach students of some of the reviewers. None of the reviewers had any experience in designing and developing educational-software materials.

Shenton (2004) suggested that credibility is increased if there are strategies that help to ensure the honesty of participants. The feedback of all of the reviewers and pilot students was analyzed to ensure that it made sense from an instructional perspective. Consequently, it would be obvious if a suggested change was for a nefarious reason. However, there was no expectation that honesty would be an issue in that the reviewers volunteered to support the research, were intrigued with the research, and hoped that the findings would be positive as the resulting resource could be a benefit to other learners. The pilot students were paid a fair salary for their time (\$50 Canadian for an expectation of about five hours of work). Although it was possible that they would not work hard, the pilot students would not gain by being dishonest.

Allrich (2002), Shenton (2004), and Yin (2003) stated that member checks help to ensure credibility. Member checks by the reviewers occurred automatically because each suggested change was built into a subsequent version of the intervention, unless, through a discussion, it was determined that the change should not be implemented. The reviewers checked subsequent versions of the paper-based materials and would likely have noticed any changes that were not made. Once the paper-based materials were finished, the reviewers checked the educational-software intervention. If the educational software, which was created from the paper-based intervention, did not contain a suggested change, it would presumably have been noticed. It is likely that some or all of the reviewers would have not continued to volunteer their time if they felt that they were not being listened to.

Another factor that enhances credibility is a detailed description of the materials (Shenton, 2004). Extensive details are provided about the entire instructional design and development process, including what was done for each of Gagné's Nine Events of Instruction. These details are found above in this Methodology chapter and Appendix C. As well, the pre-tests and post-tests are included in Appendix B.

Transferability

In qualitative analysis, transferability must come through analyzing information because the researcher was limited to the individuals and/or environment that were a part of the study. Consequently, it was imperative for the investigator to provide rich information so that others can, to some degree, decide if the findings of the current research apply to their population and/or situation (Enniss, 2006; Hugo, 1989; Shenton, 2004). The Research Design section of Chapter 3 and Appendix C present details about what was done throughout the instructional design and development process. Following an established method for creating the instructional materials supports generalizability

in that the method can be replicated (Singh, 2009). As well, the varying backgrounds of the reviewers may have helped to make the evolving and resulting materials applicable to a broader population than if the reviewers all had similar characteristics. Similarly, the feedback provided by pilot students of differing abilities may have helped to create materials suitable for a broader population.

To approximate the extent to which the qualitative findings apply to other situations, further studies are needed as little related research has been done with respect to developing and designing stand-alone paper-based resources and educational software that teach logical-thinking skills.

Dependability

According to Shenton (2004), in quantitative analysis, reliability is based on “if the work were repeated, in the same context, with the same methods and with the same participants, similar results would be obtained” (p. 71). However, the very nature of qualitative research makes reliability challenging in that the emerging results are specific to the conditions of the study at that time (Enniss, 2006; Hugo, 1989; Shenton, 2004). If this research was to be repeated with the same individuals and conditions in the future, small changes would be expected since experience in participating in this research could lead to variations in the materials, such as word choices for instructions or feedback.

Rather, dependability can be achieved if the processes of the study are fully described so that a researcher could attempt to replicate the work in the future, even though he or she would not likely achieve the exact same results (Allrich, 2002; Enniss, 2006; Shenton, 2004). The processes of this study are depicted within the Theoretical Framework section of Chapter 2 and in this Methodology chapter. Since credibility and dependability are closely tied, if credibility is demonstrated then some dependability is

also ensured (Shenton, 2004). Credibility is discussed in detail above. As well, Shenton (2004) stated that overlapping methods also support dependability. In this study, overlapping methods were demonstrated through triangulation, as discussed above. Shenton (2004) also suggested that the research methodology should be fully described to enable future researchers to understand what was done so that they can conduct a similar study. In this study, this methodology chapter, the Theoretical Framework section of Chapter 2, Appendix B, and Appendix C provide information that is needed to replicate this study.

Confirmability

The key issue with respect to qualitative confirmability is whether the findings can be confirmed. To achieve confirmability, the researcher must take steps to ensure that the findings are a result of information gained from the informants as opposed to reflecting the opinions or preferences of the researcher. Confirmability can be achieved through triangulation, the researcher admitting his or her predispositions (as is done below), and rich descriptions of the process and results (as is done in this report) (Ennis, 2006; Hugo, 1989; Shenton, 2004).

In this study, a number of steps were taken to ensure that the resulting instructional materials were based on information gained from the reviewers. Interviews with reviewers were semi-structured with open-ended statements and questions to freely generate ideas.

As discussed above, in the analysis phase, a reviewer worked with the researcher to define the actual problem through to writing the learning outcomes.

As presented above, in the design phase, some pre-test and post-test questions were written by the researcher to be comparable to the level assessed by official exams of the Canadian government for grade six and seven students, while for others, the

researcher interviewed a reviewer to determine the level to which these skills should be assessed. The reviewers were asked to provide written feedback on whether the pre-test and post-test questions for each skill matched the skill being assessed.

Given that none of the reviewers had experience in screen and user-interface design, the researcher showed reviewers a sample of educational software that the researcher thought had a screen design and user-interface that would be effective for grade six and seven students. To minimize the effects of researcher bias, the researcher stated to the reviewers that he had not previously developed educational-software materials for students as young as grade six and seven and then asked, “What should be done differently with respect to the screen and user-interface design to make this work for grade six and seven students?” A reviewer stated that “the menus should have cartoon images”. This idea was implemented into both the educational-software and paper-based interventions.

With respect to the instructional strategies, the researcher interviewed reviewers to determine how they would, in general, gain a student’s attention and teach logical-thinking skills. The methods used to gain and maintain attention included the reviewers’ recommendations to “ask the students to obtain high scores”, “stress the importance of thinking carefully”, “make the materials highly interactive”, and “pose challenging statements and questions”. Some of the instructional strategies were based on the reviewers’ recommendations for teaching logical-thinking skills, which included that it was important to “ask numerous questions”, “stimulate a high level of thinking”, and “gradually increase the difficulty of the content”. The researcher combined those ideas with his own knowledge and experience in creating instructional materials to design the instructional strategies for the learning outcomes. One of the reviewer’s ideas was modified to make it suit stand-alone delivery methods. For example, one reviewer stated

that a strategy she used to enhance higher-order thinking skills is, “I answer a student’s question with a question.” This is not possible with most stand-alone materials. However, the key to the aforementioned strategy is to frequently encourage thinking and this idea was applied to the design of the resources. For example, rather than simply stating how to do a skill, each sample problem asked students to think about the answer(s). For example, the following portion of a sample for teaching patterning skills illustrates the emphasis on thinking:

On the initial page:

“Of the following, which do you think are floxes? Turn the page to find out.
N U W X Y”

On the subsequent page:

“The floxes are highlighted below.
N U W X **Y**”

Think about why they are floxes. Check shapes, pieces that form letters, symmetry, enclosed spaces, openings, direction of openings, and sound. Turn the page to see if you are right.”

On the last page of that sample:

“Each flox is made from three straight segments.”

Note that “floxes” is a non-sensical term. Reviewers stated that non-sensical terms help students learn the patterning skill.

In this task of creating instructional strategies, the researcher’s bias would have influenced the design of the initial instructional materials. The researcher was confident in his design decisions because he had much more expertise than the reviewers in designing stand-alone educational materials, in that reviewers’ main teaching expertise was in teaching students in a traditional setting but using interactive methodologies. However, researcher bias was mitigated in the following development phase in that the reviewers provided feedback on the initial instructional strategies that the researcher designed.

In the development phase, the reviewers provided feedback on all of the instructional materials. The suggestions of the reviewers were implemented, as was applicable, into the emerging instructional materials. The reviewers could see that their suggestions were incorporated because they reviewed subsequent iterations of the instructional materials. For example, when teaching the sequencing skill, a reviewer suggested, “The pattern of how the numbers change should be shown directly below the sequence of numbers.” For example, in one sample problem in the initial version of the materials, after the learners were asked, “What is the pattern of how the numbers change?”

On the next page the learners were shown:

“Given: 4 6 7 9 10
Pattern: Alternating between adding 2 and adding 1.”

In the resulting materials based on reviewer feedback, the sample contained:

“Given: 4 6 7 9 10
 +2 +1 +2 +1
Pattern: Alternating between adding 2 and adding 1.”

The performance scores of the pilot students were low on the patterning skill and high on the deductive-reasoning skill. The researcher presented this information to a reviewer and discussed possible remedies. Regarding the patterning skill, the reviewer stated, “More samples and more questions and feedback are needed.” With respect to the deductive-reasoning skill, the reviewer said, “The problems could contain more complex relationships, such as one being greater than another.” Extra content was created for all of the corresponding sections of the intervention. The reviewers saw these changes in the next version of the instructional materials.

Confirmability in this research has also been achieved through triangulation, as discussed above within the concept of credibility. As well, rich descriptions of the process and results are described in this methodology chapter and Appendix C. In

general, with respect to confirmability, since the reviewers and pilot students were asked to answer open-ended questions, it suggests, according to Allrich (2002), Parsons (2008), and Singh (2009), that the researcher did not pre-determine the viewpoints of the reviewers or pilot students, which is important during a qualitative analysis.

In summary, the researcher addressed trustworthiness in the qualitative analysis through taking steps to ensure that there was credibility, transferability, dependability, and confirmability.

3.1.5 Quantitative Methods

“Quantitative research is about gathering numerical data to explain a particular event (Muijs, 2004)” (McNamee, 2011, p. 53). The intention of the quantitative analysis of this study was to statistically determine whether the instructional interventions developed through the qualitative research effectively taught logical-thinking skills.

Pre-test and Post-test Design

For the quantitative analysis component of this research, an experimental pre-test, post-test, control group design was used as this design inherently has relatively high internal validity. In a foundational book, Campbell and Stanley (1966) called the pre-test, post-test, control group design a “true experimental design” and recommended the design strongly. This design has strong internal validity with respect to history, maturation, testing, instrumentation, regression, selection, mortality, and interaction of selection and maturation (Campbell and Stanley, 1966). The control group is essential. Without a control group, one cannot be sure that changes were a result of the intervention or other factors (Bessick, 2008). Kaplan (1997) and Mitchell and Jolley (1988) also strongly recommended the pre-test, post-test, control group design as this

design enables one to conclude that the differences between the groups on the post-test scores can be attributed to the treatment rather than extraneous factors.

Each participant was given five pre-tests; one on each of the five logical-thinking skills that would be taught through the intervention. Based on the cumulative results of all of the pre-test scores, stratified random sampling was used to ensure that proportionate numbers of male and female and grade six and seven students of equivalent overall logical-thinking ability, were assigned to each experimental group and the control group. Based on recommended practice (Abramis, 2008), the total scores from the five pre-tests were used to differentiate the range of initial logical-thinking ability.

Through the duration of this study, all of the students were in their regular classrooms except for when the intervention took place, as recommended by Etsey (2004) who stated,

For the design to yield accurate results, the experimenter should try to provide identical experiences to the experimental and control group as much as possible, except for the one condition that the experimental group is exposed to an experimental treatment (Gall et al., 1996) (p. 120).

During the time of the intervention, the control students were in a classroom where they completed the post-test and then participated in a traditional classroom activity, such as a reading assignment, that was unrelated to the logical-thinking skills being taught to the experimental groups. At the same time, one experimental group worked through the educational-software intervention in the school's computer lab while the other experimental group worked on the paper-based intervention in another school classroom. The experimental students worked independently of each other and were given the time they needed to learn from the resources. Providing the time needed to learn was important as Collins (1984) found that students with lower initial logical-

thinking skills needed more time to master the formal logic concepts taught. Immediately after the intervention, the students in the experimental groups were given the post-test. If the post-test was not immediately completed, the students of the same or different groups could have talked with each other about the interventions when they returned to their regular classrooms. This could potentially have introduced a factor of cooperative learning that may have impacted the results (Asamani, 1998).

The independent variable was the treatment or no treatment. The dependent variable was the score in logical-thinking ability.

3.1.6 Internal Validity

Without internal validity, an “experiment is uninterpretable” (Campbell & Stanley, 1966, p. 5). The eight common threats to internal validity are history, maturation, testing, instrumentation, regression, selection, mortality, and interaction effects. If these threats are not addressed, there is a risk that the post-test scores could be impacted. The extent of the impact can be such that the observed changes could be attributed to the intervention when otherwise the findings would be insignificant. A true experimental design controls effectively for all of the main threats to internal validity. (Campbell & Stanley, 1966)

As defined by Campbell and Stanley (1966) a true experimental pre-test, post-test, control group design is as follows where R represents randomization, O represents the test (pre-test and post-test), and X represents the intervention:

R O X O

R O O

The design used for this study is depicted below, where X_P represents the paper-based intervention and X_E represents the educational-software intervention.

O R X_P O

O R X_E O

O R O

As compared to Campbell and Stanley's (1966) design, the variation was that the design of this research entailed stratified random assignment of members to groups after the pre-test. Stratified random assignment was done to increase the chance that each group had similar abilities in logical-thinking skills. With stratified random assignment to groups, the experiences of members of one group with respect to the threats to internal validity would likely be equally experienced by members of the other groups. More details regarding each of the threats to internal validity are described below.

History

History refers to the "specific events occurring between the first and second measurement in addition to the experimental variable" (Campbell & Stanley, 1966, p. 5). Extraneous factors due to the time interval between the pre-test and post-test were not expected to significantly impact the results since the time between the pre-tests and the final post-test was five weeks. As well, history should have had minimal impact since logical thinking was not directly addressed within the curriculum or in events the students were likely to experience. The likelihood of a history effect was yet smaller given the logical-thinking skills taught within the intervention were very specific. To minimize the potential of history effects, teachers were asked to not purposely teach logical-thinking skills through the duration of the study. As well, the teachers were asked to tell their students to not discuss the pre-test or intervention amongst themselves.

Maturation

Maturation is the “processes within the respondents operating as a function of the passage of time per se (not specific to the particular events), including growing older, growing hungrier, growing more tired, and the like” (Campbell & Stanley, 1966, p. 5), which can be summarized as biological and psychological factors. Given the five week duration of the study and the approximately one-hour duration of each intervention, factors like growing older, hungrier, and more tired were not expected to impact the results. However, with the control students, there may have been a maturation effect due to disinterest with respect to performance on post-tests. This was minimized through the researcher asking the teacher to encourage the students to try hard on each post-test as it would help ensure that the results of the scientific research are valid.

Testing

Testing is defined as the “effects of taking a test upon the scores of a second testing” (Campbell & Stanley, 1966, p. 5). A typical effect is that students often perform better on the second test than the first test even if the test is different (Campbell & Stanley, 1966). Effects due to testing were minimized through having comparable but different pre-tests and post-tests. The pre-tests and post-tests were reviewed by reviewers to ascertain that they were equal in content and difficulty and appropriate for the students of this research. It was decided to have different pre-tests and post-tests because, according to one of the reviewers who formerly taught at the school of this study, some participants, particularly brighter students, would potentially try to remember some questions and later work out the answers. To minimize the effect of a post-test gain due to the experience gained from writing the pre-test, students were not told their scores or the correct answers. As well, the test design was familiar to students

and they were given an example of how to answer the questions in the instructions of each test. A familiar test design was used to minimize the typical gains that are seen from writing a second exam. As well, in this way, the students would not lose marks, particularly on the pre-test, because of not knowing how to answer the questions.

Instrumentation

Instrumentation refers to when “changes in the calibration of a measuring instrument or changes in the observers or scorers used may produce changes in the obtained measurements” (Campbell & Stanley, 1966, p. 5). Instrumentation was not expected to be a factor in this research in that the format of the pre-tests and post-tests was identical, the pre-tests and post-tests were assessed to be equivalent, and scoring was entirely objective.

Regression

Regression towards the mean can occur when “groups have been selected on the basis of their extreme scores” (Campbell & Stanley, 1966, p. 5). Regression towards the mean was not expected to influence the findings of this research since students were placed into the groups through stratified random sampling.

Selection

A major threat to internal validity is whether the experimental and control groups are equivalent. If there is a differential selection of respondents in the comparison groups, there can be a bias in the results (Campbell & Stanley, 1966). There should not be a selection bias in this study, given that all of the grade six and seven students in the four classes were invited to participate in the study, except for three students that the teachers decided to not invite to participate. One student had a limitation in language ability and two students needed to attend their special learning

assistance sessions. As well, all but one of the students invited to participate in the research study received permission from their parent or guardian to participate in the study. Since almost all of the possible students did participate, there was no bias created by selecting the first volunteers. In particular, the threat of selection bias was minimized through using stratified random sampling, which gave each student an equal chance of being placed into each group. Stratified random sampling ensured that the control and experimental groups had equal numbers of grade six and seven males and females with equivalent initial logical-thinking abilities. Stratified random sampling was particularly important for this study because students were not randomly assigned to their regular classrooms.

Mortality

Mortality is the “differential loss of respondents from the comparison groups” (Campbell & Stanley, 1966, p. 5). Mortality was expected to be minor given the experiment was to be completed over five weeks. For example, it was anticipated that a few students would not complete everything due to events such as an illness. However, due to the stratified random assignment of students into groups, each group had an equal chance of being affected by mortality.

Interaction Effects

Interaction effects can occur in quasi-experimental designs, such as non-equivalent control group designs (Campbell & Stanley, 1966), when the effect of one independent variable is impacted by another independent variable. Given the independent variable is the instructional interventions and stratified random sampling was used to generate groups with equivalent initial logical-thinking skills, no interaction effects were expected.

Other Effects

Other threats to internal validity were expected to be minimal. These threats include an experimenter effect, teacher effect, administrator effect, subject effect, novelty effect, non-response bias, effect from the time of day, not having enough time to complete the intervention or write the tests, content validity, and socioeconomic differences.

There should not have been an experimenter effect since the intervention was completed entirely within the educational-software and paper-based resources. As well, the teachers, rather than the researcher, supervised the groups.

Teacher effects should have been minimal since the teachers did not have a personal vested interest in the instructional materials, the skills taught by the instructional materials were not being compared to their own skills in teaching, teachers did not need special training, and the teaching was entirely done through the intervention materials. As mentioned above, teacher enthusiasm was helpful. It was likely that the teachers were enthusiastic or they would not have agreed to support the research.

This study had no negative effects from the level of administrative support. The Principal agreed to have the research conducted at his school because the interventions supported the school's specific goal for the year of increasing higher-order thinking skills. From an administrative perspective, there was no expensive hardware and/or software required to be purchased and the time needed for students to be away from regular class activities was acceptable.

There may have been a subject effect in that some students could have been self-conscious about having their ability to think logically assessed. To help minimize any pressure or discomfort due to this, the teachers were asked to tell the students that the

focus was to find out if the interventions can teach each one of them more logical-thinking skills than they already had; whereby the emphasis was on the ability of the intervention as opposed to their individual skills.

It was not expected that there would be an important novelty effect for the educational-software intervention as the students were all familiar with computers and have used a number of different software packages for completing school assignments.

To prevent non-response bias, all students participating in the study were expected, but not required, to complete the pre-test or post-test given that day.

To minimize the possibility of the time of day being a factor in performance, all of the students wrote each pre-test and post-test within the same block of time and all of the pre-tests and post-tests were completed in the morning. This was important since the time of day can be a significant factor in academic performance (Dunn & Bruno, 1985; Goldstein, Hahn, Hasher, Wiprzycka & Zelazo, 2006).

Through prior testing with pilot students, the amount of time needed for individuals to work through each of the pre-test, instructional activities, and post-test was noted. Based on this, some extra time was allotted for the formal research activities to ensure that the students had the time they needed for each task. This ensured that the time needed for learning and to complete the tests did not influence the results.

The content was validated from the perspective that an acceptable way to ensure content validity is to have external experts conduct a detailed review to ensure that the content is suitable for the students, is complete within the context of the research, and does not contain extraneous material (Lieberman, 2007). The content was thoroughly and independently reviewed and validated by six reviewers, as described above.

Socioeconomic differences can impact achievement on higher-order thinking skill tests (Bessick, 2008; Sondel, 2009). However, it would have been unwise to

incorporate the socioeconomic data of the students into the results of this study as that information tends to be viewed as highly personal and asking for that information would presumably have resulted in some parents not granting permission for their children to participate in the study. Instead, the stratified random assignment of each student to a group should have minimized the likelihood of any socioeconomic differences affecting the results.

In summary, the researcher minimized the threats to internal validity of the quantitative analysis through using a true experimental design. As well, a number of other strategies were used to minimize threats yet further.

3.1.7 External Validity

“External validity asks the question of generalizability: To what populations, settings, treatment variables, and measurement variables can this effect be generalized?” (Campbell & Stanley, 1966, p. 5) Threats to external validity involve the treatment interacting with another variable. There could be threats to external validity due to pre-testing, the school not being typical, and students behaving differently due to participating in an experiment (Campbell & Stanley, 1966).

With respect to the threat to external validity due to pre-testing, the effect should be minimal since the students are used to being tested, as is typical in educational settings (Campbell & Stanley, 1966).

The first school district, which the researcher approached for conducting the study, turned down the request due to the amount of research that was already being conducted in the district. Approval for conducting the research was given by the second school district approached. However, the school in which the research took place was not necessarily representative of all schools. The school had a history of teaching logical-thinking skills and the school needed to formally assess gains in logical-thinking

skills to achieve a goal set for the year. This could have led to a main-effect due to the school itself. However, stratified random assignment of students to each group should have resulted in there being no differences in the effect between groups since each group should experience the effect of the school equally.

It is possible that students behaved differently than they would in a normal school situation simply because they knew that they were participating in an experiment. Again, stratified random assignment of students into each group likely made any effect equal across the groups. As well, the teachers discussed with the students the need for research and encouraged the students to try hard on each test as it would help ensure that the results of the scientific research are valid.

As discussed above, the threats to external validity, due to pre-testing, the school not being typical, and students behaving differently due to participating in an experiment, were not expected to impact the findings.

3.1.8 The Treatment

The experimental groups worked through either the educational software or the equivalent paper-based materials that contained instructional content designed to enhance logical-thinking ability. For the students of the experimental groups, the interventions taught the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

1. Classification Skill

For the classification skill, students were given three words and a list of five words from which to choose one more word. Students had to determine which word from the list had the same thing in common with the given words. During the intervention, students were presented with elaborative feedback as to whether they were

right or wrong and were told about the logic connecting the common words. The goal was to get as close to 100% correct as possible.

2. Analogical-reasoning skill

For the analogical-reasoning skill, students were presented with a pair of words, one word out of an analogous pair of words, and a list of five words from which to choose the missing analogous word for the second pair. Students had to use logic to determine which listed word fit the missing word in the second pair.

During the intervention, with each answer choice, students were told whether they were right or wrong and were presented with the logic needed to match the analogous pair. The goal was to get as close to 100% correct as possible.

3. Sequencing Skill

For the sequencing skill, students used numerical logic to find the next two numbers of a sequence of numbers given a list of five possible answers. During the intervention, upon each answer selection, students were given detailed feedback as to whether their selection was correct or not and the logic needed to successfully find the next two numbers.

The goal was to answer the questions with as few incorrect selections as possible.

4. Patterning Skill

For the patterning skill, students were presented with a number of visual items that had one or more common characteristics between them as well as a number of items that do not have the characteristics. Using logic, the students then determined which of the potential answers, where one to three of the five answer choices were correct, had the same common characteristics as the initial series of items.

The goal was to get as many right answers as possible while making as few mistakes as possible.

5. Deductive-reasoning skill

In the deductive-reasoning skill, students were provided with text information and a question to answer using a presented matrix.

In the educational-software intervention, during the practice activity, students were able to select any matrix square that they felt represented a new conclusion based on the information already known. Each correct conclusion led to one or more conclusions being possible. If incorrect, they were told, with the information known so far, that conclusion could not be made.

In this activity, it was not possible to create paper-based materials that exactly matched what can be done within educational software. In the paper-based materials, during the practice activity, students were able to gradually fill in the matrix based on logic. At any time, the learner could check their work against a number of hints that gradually led to the correct answer.

The goal was to complete every problem correctly with as few mistakes as possible.

3.2 Population and Sample

The population and sample consisted of reviewers and students. The reviewers participated in the qualitative assessment. There were two different sets of students. One set was involved in the qualitative assessment and the other set participated in the quantitative assessment.

3.2.1 Reviewers Participating in the Qualitative Assessment

For the qualitative assessment, six reviewers participated in the study. One reviewer, a highly-experienced, late-career teacher, has taken a number of post-secondary courses aimed at teaching gifted children a variety of higher-order thinking skills that include logical-thinking skills, has attended conferences to increase her skills in this area, has years of related experience through teaching thousands of gifted children, worked as a gifted children's consultant to design instructional materials that specifically enhance logical thinking, has taught mathematics to elementary school children, which is a subject that inherently requires logical thinking to solve problems (Wolfe, 1999), and has led numerous workshops aimed at developing the abilities of other teachers in building the logical-thinking skills of their students. Another reviewer, who was also a highly-experienced, late-career teacher, taught mathematics to elementary school children, was a math department head, and worked as a mathematics consultant. One reviewer was a mid-career teacher who has taught mathematics to elementary school children. Three reviewers had extensive training in logical thinking and mathematics through participation in their school's program for those who were formally assessed as being gifted, and had tutoring experience.

In general, the reviewers were selected because of their experience related to logical-thinking as opposed to credentials. In British Columbia, Canada (the region where this study took place), one cannot earn a provincial designation that shows that one has expertise in teaching logical-thinking skills as there are no such programs in the province. One can take post-secondary courses on teaching gifted children, however, these courses do not specifically focus on how to teach logical-thinking skills. Although advanced degrees can be earned in philosophy, these programs do not develop an individual's skills in how to teach logical thinking. Consequently, expertise can come

through taking courses in teaching gifted children, experience in teaching gifted children, experience and training in teaching mathematics, being trained in using logic, and being taught mathematics. The knowledge gained must then be applied to create instructional materials that teach logical thinking because there was no provided curricula for teaching logical-thinking skills in the province of British Columbia, Canada (B. Johnson, personal communication, June 14, 2015).

3.2.2 Students Participating in the Qualitative Assessment

There were six pilot students. Of these students, three were male and three were female. Three were in grade six and three were in grade seven. They ranged from weak to strong academically, as assessed by their parents through an analysis of their previous semester's examination results. They were deliberately selected to broadly represent the sample that was to participate in the study and the general population.

3.2.3 Students Participating in the Quantitative Assessment

The student population in the quantitative portion of this study was public-school grade six and seven students from one urban elementary school in Burnaby, British Columbia, Canada. The entire grade six and seven population of this school consisted of 102 students. The sample was drawn from the 102 students. 96 participants completed both the pre-tests and post-tests. Two participants, who wrote the pre-tests, did not participate in the rest of the study. One was absent due to medical reasons while the other voluntarily withdrew from the study. Three students were not invited to participate based on a decision by their teachers. One student was deficient in English language skills and two students instead attended their regular special instructional session due to their need for learning assistance. One student was not given permission to participate in the study.

Table 3.2

Gender of Sample

Gender	Educational Software Intervention Group	Paper-based Intervention Group	Control Group	Total
Male	17	17	16	50
Female	15	15	16	46
Total	32	32	32	96

Table 3.3

Grade and Age of Sample

Grade	Age	Educational Software Intervention Group	Paper-based Intervention Group	Control Group	Total
Six	Eleven	16	16	17	49
Seven	Twelve	16	16	15	47
Total		32	32	32	96

Table 3.2 describes the gender of the sample. A total of 50 participants were male while 46 were female. Table 3.3 describes the grade level and ages of the sample. Of the 96 participants, 49 were in grade six and were eleven years old, while 47 were in grade seven and were twelve years old.

The elementary school was not randomly chosen. The school was chosen based on the expected support of the school's principal as well as the teachers. This support stemmed from the school having a specific goal for the year of increasing logical-thinking skills. However, for the grade six and seven students, the school did not have specific resources for both teaching and assessing logical-thinking skills, where an assessment was needed to determine whether or not the goal had been achieved. Consequently, there was a mutually-beneficial situation where this researcher needed a school in which to conduct the research and the school needed the resources that this researcher could provide.

The school was not entirely representative of typical schools in that the school of this study is located in an upper middle class neighbourhood. As well, the school had a history of teaching logical-thinking skills and high academic performance. Consequently, the average initial logical-thinking abilities of the students were likely to be higher than average. This could have negatively affected the amount of gains on the post-test, as compared to more stereotypic schools.

Grade six and seven students were the subjects selected for this study as they were expected to have the ability to learn the specific logical-thinking skills taught through the interventions based on their expected level of cognitive development (Liu, 2006) and the opinions of two reviewers who have taught the logical-thinking skills of the interventions to grade six and seven students.

3.3 Instrumentation

As this was a mixed-method research study, both qualitative and quantitative research instruments were used. These instruments are discussed below.

3.3.1 Qualitative Research Instruments

Gagné's Nine Events of Instruction has the attributes of gaining attention, informing the learner of the learning outcome, stimulating recall of prerequisites, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer (Gagné et al., 1988). Gagné's Nine Events of Instruction was followed when designing the instructional materials. A qualitative assessment of these events was conducted to determine whether the educational software and paper-based materials that were developed had the attributes of Gagné's Nine Events of Instruction for teaching logical-thinking skills.

Gaining attention

For this event, through written feedback, the reviewers were asked to review the content and state what needed to be changed.

Informing the learner of the learning outcome

Through written feedback for this event, the reviewers were asked to identify anything that needed to be changed.

Stimulating recall of prerequisites

In this study, recalling prerequisites was not needed as a part of the instructional strategy since the skills were taught from a foundational level that was suitable for grade six and seven participants.

Presenting the material

For this event, through written feedback, the reviewers were asked to review the content and state what needed to be changed. In particular, the reviewers were asked to provide feedback on where the instructional strategies could be improved, given the target audience was grade six and seven students, and identify any text that does not make sense or could be written more clearly.

Providing learning guidance, Eliciting the performance, and Providing feedback

Providing learning guidance, eliciting the performance, and providing feedback are often integrated with each other within instructional materials (Fenrich, 2014), as was done in the interventions of this study. To ensure the attributes of providing learning guidance, eliciting the performance, and providing feedback were contained within the interventions, during their review, the reviewers were asked to provide written feedback when an answer to a question in the instructional materials was

incorrect, an incorrect answer to a question in the instructional materials was not believable, and the feedback to the answer of a question in the instructional materials was inaccurate or incomplete.

Assessing performance

To ensure that the assessing performance attribute was a part of the intervention, the reviewers were asked to provide written feedback for when an answer to a test question was incorrect, an incorrect answer to a test question was not plausible, a test question was not suitable for grade six and seven students, a test question did not accurately assess a corresponding logical-thinking skill, a pre-test was not equivalent to the post-test, and if students would not know how to answer the questions.

Enhancing retention and transfer

With respect to the enhancing retention and transfer attribute, the reviewers were asked to provide written feedback when there were not enough problems and solutions for retention and transfer to take place, not enough practice questions and feedback to support retention and transfer, and when the samples and summaries did not support retention and transfer.

Summary: Qualitative research instruments

In summary, through the entire design process, the reviewers provided their ideas as to what should be contained in the instructional materials and then continually reviewed the revised materials until they were satisfied with the final product.

3.3.2 Quantitative Research Instruments

As discussed in the literature review chapter, none of the commercial assessment tools were suitable for the quantitative component of this study. Consequently, as often

needs to be done (Reed, 1999), the researcher created the assessment instruments. It is important that the testing instruments have both reliability and validity. Reliability of the testing instruments was determined through calculating Cronbach's alpha, as reported in Chapter 4. Validity was created in a number of ways.

To achieve validity, the researcher created pre-test and post-test questions that closely paralleled the questions used in the interventions, in that each pre-test and post-test question was phrased and presented in the same way as those within the interventions. As well, the same kind of thinking (i.e., the logic needed to solve classification, analogical-reasoning, sequencing, patterning, and deductive-reasoning skills) that was used in the intervention was required to answer each pre-test and post-test question. Furthermore, for each pre-test and post-test question, the logic of the relationship itself that was needed to determine the answer was covered within the intervention, except for the test questions that addressed transfer of learning. With the aim of internal consistency as a guiding principle, each test question was deliberately designed to measure a corresponding specific logical-thinking skill, notably classification, analogical reasoning, sequencing, patterning, and deductive reasoning, as defined in Chapter 1. The pre-test and post-test instructions and questions are found in Appendix B.

Beyond the validity created by the researcher, the pre-test and post-test questions for each logical-thinking skill were validated by reviewers. The reviewers evaluated the questions for appropriateness for the cognitive development level of grade six and seven students, whether the questions accurately assessed the corresponding logical-thinking skill, and whether the pre-tests and post-tests were equivalent to each other.

3.4 Data Collection Procedures

As needed for a mixed-method research study, there were both qualitative and quantitative data collection procedures. These procedures are discussed below.

3.4.1 Qualitative Data Collection Procedures

The qualitative information from the reviewers was gathered through semi-structured interviews and written feedback throughout the instructional design and development process, which is described in detail in the above topic entitled, “3.1.2 Qualitative Analysis Within the Combined Instructional Design and Development Model”.

3.4.2 Quantitative Data Collection Procedures

For each student, his or her name, grade, age, and gender were recorded. Each student was assigned a numerical identification. This numerical identification was the only cross-reference to the individual student.

For the pre-tests and post-tests, the input from the students of the control and experimental groups was marked and recorded manually. Since there were no subjective answers, there was no need for a comparative analysis as the data could not be interpreted in any other way.

Pre-test and Post-test

The pre-tests and post-tests were conducted on paper. The questions were designed to be solved using the logical-thinking strategies that were presented to the experimental groups. The pre-test and post-test questions contained instructions on how to complete each activity, did not provide any feedback or scores, gradually increased in difficulty, in general, and were different but comparable to the material presented in the

interventions. Each pre-test and post-test contained at least one question containing a relationship or concept that was not specifically taught in the treatment to ascertain whether the skills learned can transfer to new situations. This transfer of skills is defined as “near transfer” where the students apply what they learned in the interventions to related problems that are at a similar level of difficulty. The data recorded was whether each question was completely right or wrong. For the pre-test and post-test, there were ten classification skill questions, containing two transfer of skill questions, ten analogical-reasoning skill questions, containing two transfer of skill questions, ten sequencing skill questions, containing one transfer of skill question, ten patterning skill questions, containing two transfer of skill questions, and ten deductive-reasoning skill questions, containing two transfer of skill questions.

3.5 Data Analysis Procedures

For this mixed-method research study, both qualitative and quantitative data analysis procedures were followed. These procedures are discussed below.

3.5.1 Qualitative Analysis Procedures

Gagné’s Nine Events of Instruction provided the framework for instructional design. A qualitative assessment of these events was conducted to determine whether the educational software and paper-based materials had the attributes of Gagné’s Nine Events of Instruction for teaching logical-thinking skills. The specific feedback that the reviewers were asked to provide for the instructional events are listed above in the discussion on instrumentation. Feedback was provided in written form.

Throughout the events of instruction, the reviewers provided their suggestions with respect to how the content should be taught and what the content should contain. The instructional materials continually evolved as their suggestions were applied. After

the reviewers completed their reviews, the materials were ready for testing with pilot students. Revisions were made based on what was learned from the pilot students. The evaluation and revision continued until the reviewers had no further feedback to give.

3.5.2 Quantitative Analysis Procedures

For the quantitative analysis, all of the statistical tests assumed a significance of 0.05.

Statistical analysis was done on the overall scores based on the sum of the test scores from all of the questions on the five logical-thinking ability tests, test scores from all of the questions on each logical-thinking ability test, direct scores based on the sum of the test scores from all of the non-transfer questions on the five logical-thinking ability tests, direct scores based on the test scores from all of the non-transfer questions on each logical-thinking ability test, and the transfer of skills question scores summed from the transfer questions from all five logical-thinking ability tests. All of this data is quantitative. Cronbach's alpha was calculated to determine the internal consistency of the tests.

One-Way ANOVA / Tukey HSD Post Hoc Test

One-way ANOVAs were conducted for the following research questions. If significance was found between the groups, a Tukey HSD Post Hoc Test was done.

- Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?
- Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?

- Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?
- Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?
- Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?
- Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

With respect to these research questions, paired samples t-tests were calculated to determine the percent gained for each group. The t-tests compared the pre-test and post-test total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, total direct learning scores, direct learning scores on each specific logical-thinking skill, and total transfer learning scores from the transfer questions on each logical-thinking skill test for each group.

3.6 Approvals

The initial step was getting support from the Principal of a public elementary school. After this, the Principal obtained School District permission to have the research conducted at his school. Once the four grade six and seven teachers in the school agreed to support the research, a letter was sent to the parents of the students requesting their approval to have their children participate in the study.

The letter stated the goals of the study, that human rights will be respected, that there are no physical or mental risks to the students, that all data recorded will remain confidential, the researcher will be the only person to have access to the raw data, no identifying information other than the student's numerical code will be associated with any of the collected data, that published results will be reported as group results rather than individual performance, the original data will be stored in a locked cabinet for seven years after completion of the study after which time the data will be destroyed, that their school will be presented with the results of the study, that they can receive a free electronic copy of the results if they provide an email address, that each parent is free to decline from having their child participate in the study, the researcher's contact information so that they can have questions answered and/or concerns addressed, that they can withdraw their child from the study at any time, and that the school district will be given a free copy of the final software regardless of whether their child participated in the study.

The letters are contained in Appendix A.

3.7 Summary

The third chapter of this report presents the methodology that was used in the study. The topics discussed are the research design, the population and sample, instrumentation, data collection procedures, data analysis procedures, and approvals. Within research design, the qualitative method, qualitative analysis in each instructional development cycle phase, trustworthiness of the qualitative analysis, quantitative methods, internal validity, external validity, and the treatment are discussed. The population and sample, instrumentation, data collection procedures, and data analysis procedures topics address both the qualitative and quantitative aspects of the study.

Chapter 4

Findings

4.0 Introduction

The objectives of this study led to the formulation of the following research questions:

1. Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?
2. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?
3. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?
4. Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?
5. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?
6. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?

7. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

This chapter presents the findings from the data collected and analyzed to answer these research questions.

4.1 Research Question 1

1. Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?

4.1.1 The Context

Given that educational materials that teach grade six and seven students logical-thinking skills needed to be created, reviewers were sought who could provide advice on how to teach the concepts. Participant selection was purposeful to gain the needed rich and varied feedback, as is warranted for this kind of qualitative research (Allrich, 2002; Enniss, 2006). After the educational materials were developed, a qualitative analysis was conducted to determine whether the educational software and paper-based materials had the attributes needed to teach logical-thinking skills.

4.1.2 The Attributes

Using Gagné's Nine Events of Instruction as a basis for qualitatively assessing the effectiveness of the materials, the findings were as follows:

Gaining attention

In this study, the techniques used to gain and maintain attention included the reviewers' recommendations to "ask the students to obtain high scores", "stress the importance of thinking carefully", "make the materials highly interactive", and "pose

challenging statements and questions”. These techniques also supported the need to keep students motivated.

For the gaining attention content, the reviewers were able to see that their ideas were included, and suggested a few word edits during their reviews. Given that there was no further feedback, it was deduced that the reviewers thought that the resulting instructional materials had this attribute of gaining attention.

Informing the learner of the learning outcome

In this study, the learner was informed of each learning outcome as the learning outcome was directly presented within the instructional materials. However, for the deductive-reasoning skill, for clarity from the learner’s perspective, the learning outcome was phrased as “use clues to find solutions” rather than the actual learning outcome that was to “solve matrix problems”. Based on discussions with reviewers, a major change made regarding learning outcomes was that the convergent-thinking skill, determining the solution to a problem through asking questions, was eliminated. Although traditional teaching methods can be used to effectively teach the skill, it was decided that it would not be possible to provide the interactions needed to invoke deep thinking because the fixed questions and responses required would limit thinking too much, and it was thought that the number of alternatives based on the questions selected would be too cumbersome in a paper-based intervention. A reviewer stated that the learning outcome for the sequencing skill, which was to determine the next number in a series of numbers, was too easy, given the expected cognitive ability of the students. The reviewer suggested that the learning outcome should be to “determine the next two numbers in a series of numbers”. This feedback led to that change in the sequencing skill learning outcome and corresponding changes throughout the instructional materials.

Given that there were no further recommendations, it was determined that the reviewers thought that the resulting materials had the attribute of informing the learner of the learning outcome.

Stimulating recall of prerequisites

In this study, recalling prerequisites was not needed as a part of the instructional strategy since the skills were taught from a foundational level that was suitable for grade six and seven students.

Presenting the material

The reviewers iteratively checked the instructional materials through the development phase of the instructional design and development cycle. Based on their reviews a number of changes were made. After a reviewer stated, “the menus should have cartoon images”, cartoon images were added to the menus. A reviewer felt that the sequencing skill was too easy based on the expected cognitive ability of grade six and seven students and suggested that the learning outcome be changed to “determine the next two numbers in a series of numbers”. That change was made, which led to revisions to all of the content related to that learning outcome (i.e., the instructions, samples, questions, answers, feedback, summary, formal assessment tests ...). Given that the performance scores of the pilot students were low on the patterning skill and high on the deductive-reasoning skill, the researcher discussed these results with a reviewer. In regards to the patterning skill, the reviewer said, “More samples and more questions and feedback are needed.” With respect to the deductive-reasoning skill, the reviewer said, “The problems could contain more complex relationships, such as one being greater than another.” Extra content was created for all of the corresponding sections of the intervention. Word edits were suggested and made.

The resulting materials were aimed to be appropriate for the level of cognitive development and maturity of the students. Each lesson could be completed within an hour. The concepts gradually increased in difficulty in that the material was presented in small incremental steps. This is congruent with Vygotsky's Zone of Proximal Development learning theory. A variety of instructional activities and strategies were created. The activities supported the corresponding learning outcome and were designed to motivate the learners. There was a high degree of active learning in the samples, practice questions, self-test, and challenge questions. The learner's focus was directed to the deeper learning concepts that supported higher-order thinking skills. The assimilation and accommodation of knowledge into long-term memory was supported. Principles of the constructivism theory were followed. Metacognition and self-reflection were encouraged.

The reviewers could see that the materials contained what they said was important for teaching logical-thinking skills, which was to "ask numerous questions", "stimulate a high level of thinking", and "gradually increase the difficulty of the content". As well, changes were made based on the feedback of the reviewers until no further feedback was provided. Consequently, it was reasoned that the reviewers thought that the resulting instructional materials had the attribute of "presenting the material".

Providing learning guidance, Eliciting the performance, and Providing feedback

The reviewers iteratively checked the instructional materials. One suggested change was that "a student should only receive a recommendation to proceed in the lesson if he or she scores a perfect mark or only makes one mistake on the self-test". The reasoning behind this was that higher expectations tend to lead to increased learning. The original recommendation to proceed was given if the student made two or

less mistakes in a self-test. This change was done. For teaching the sequencing skill, a reviewer stated, “The pattern of how the numbers change should be shown directly below the sequence of numbers.” Consequently, the resulting materials contained that additional feedback, which enabled the learner to clearly see how the pattern changed between each pair of numbers. As well, word edits were done based on their suggestions.

The resulting materials contained guidance for how to solve each of the skills through the presentation of the initial samples, direct statements of what needed to be done to answer the questions, numerous opportunities to practice each skill through practice, the self-test, and challenge questions, questions that were asked at the highest suitable thinking level, feedback that contained hints with increasing detail, and elaborative feedback that explained why the answer was correct and why other answer choices were incorrect, as was appropriate.

Given that changes were made based on the feedback provided by the reviewers and no further changes were requested, it was deduced that the reviewers were confident that the answers to the questions within each practice activity and self-test were correct, each incorrect answer to the questions within the practice activity and self-test had a reason that it may be selected, and the feedback to the answers of the questions within the practice activity and self-test was accurate and comprehensive. Consequently, it was deemed that the materials contained the aforementioned attributes.

Assessing performance

Through the feedback provided by the reviewers with respect to assessing performance, the resulting pre-tests and post-tests contained word edits based on their suggestions.

Given that revisions were made based on the suggestions the reviewers provided and no further suggestions were made, it was judged that the reviewers thought that the answers to the test questions were correct, incorrect answers to the test questions were credible, questions matched the expected skill level of grade six and seven students, questions accurately assessed each corresponding logical-thinking skill, pre-tests were equivalent to the post-tests, test questions paralleled but did not duplicate the questions in the instructional materials, students would know how to answer the questions, and, consequently, that the materials contained the assessing performance attribute.

Enhancing retention and transfer

Through the reviewers' iterative review of the instructional materials, the resulting materials contained word edits based on their suggestions, numerous opportunities to practice the skills, varied activities for learning the skills, simpler concepts being presented before more complex concepts, a summary that reiterated the strategy of how to solve the logical-thinking skill, a deliberate effort to teach skill transfer, challenge questions that presented content that went beyond what was covered in the "regular" parts of the material, text statements indicating that a solution can be based on many reasons, and near transfer questions.

Given that adjustments were made based on the advice given by the reviewers and no further feedback was provided, it was concluded that the reviewers thought that there were enough varied problems and solutions for retention and transfer to take place, there was enough practice and feedback to support retention and transfer, and the samples and summaries supported retention and transfer.

Summary: Did the Developed Instructional Materials Have the Attributes to Teach Logical-thinking Skills

In summary, after the materials were modified based on the information gleaned from the pilot students and all of the changes were put in as suggested by the reviewers until no further suggestions were offered, it was determined that the reviewers considered that the events of instruction addressed in this intervention (gaining attention, informing the learner of the learning outcome, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer) provided the attributes needed for the instructional interventions to effectively teach the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

4.2 Research Questions 2, 3, and 4

2. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?
3. Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?
4. Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?

4.2.1 Combined Direct and Transfer Learning

Table 4.1

Pre-test and Post-test (df=2,93) Combined Direct and Transfer Learning Scores

Test	ESG	PBG	CG	F	p	Tukey
	N=32	N=32	N=32			HSD
	Mean (SD)	Mean (SD)	Mean (SD)			Test
Pre-test Total	33.09 (8.71)	34.38 (8.78)	33.88 (8.04)	.184	.832	
Post-test Total	39.54 (6.06)	40.43 (6.34)	34.29 (8.21)	7.33	.001	ESG > CG PBG > CG
Classification Skill Pre-test	6.44 (2.65)	6.03 (2.74)	5.81 (2.78)	.434	.649	
Classification Skill Post-test	7.81 (1.31)	7.88 (1.60)	6.19 (2.71)	7.58	.001	ESG > CG PBG > CG
Analogical-reasoning Skill Pre-test	7.06 (2.20)	7.19 (2.01)	6.97 (2.22)	.084	.920	
Analogical-reasoning Skill Post-test	8.68 (1.23)	9.06 (0.91)	7.45 (2.17)	9.65	.000	ESG > CG PBG > CG
Sequencing Skill Pre-test	7.72 (1.80)	7.75 (2.06)	7.28 (2.20)	.534	.588	
Sequencing Skill Post-test	8.47 (1.65)	8.47 (1.70)	7.16 (2.44)	4.74	.011	ESG > CG PBG > CG
Patterning Skill Pre-test	4.72 (2.26)	4.78 (2.47)	4.75 (2.26)	.006	.994	
Patterning Skill Post-test	6.15 (1.90)	6.28 (2.64)	4.52 (2.43)	5.62	.005	PBG > CG
Deductive-reasoning Skill Pre-test	7.16 (3.69)	8.63 (2.52)	9.06 (1.24)	4.44	.014	CG > ESG
Deductive-reasoning Skill Post-test	8.43 (2.02)	8.75 (1.54)	8.97 (1.43)	.84	.437	

Table 4.1 presents the pre-test and post-test One-Way ANOVA results from comparing the three groups (ESG, PBG, and CG) on the total combined direct and

transfer learning scores as well as the combined direct and transfer learning scores on the five individual tests for each specific logical-thinking skill.

On the posttest, for the total combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .009$) and the PBG scored significantly higher than the CG ($p = .002$). There were no significant differences between the ESG and the PBG.

For the classification skill combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .004$) and the PBG scored significantly higher than the CG ($p = .003$). There were no significant differences between the ESG and the PBG.

For the analogical-reasoning skill combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .005$) and the PBG scored significantly higher than the CG ($p = .001$). There were no significant differences between the ESG and the PBG.

For the sequencing skill combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .024$) and the PBG scored significantly higher than the CG ($p = .025$). There were no significant differences between the ESG and the PBG.

For the patterning skill combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .017$) and the PBG scored significantly higher than the CG ($p = .010$). There were no significant differences between the ESG and the PBG.

Table 4.2

Deductive-reasoning Skill Combined Direct and Transfer Learning Scores T-test Results

Test	n	Mean difference (Post–Pre)	t (df)	p
ESG Post-test versus Pre-test	32	1.27	2.12 (31)	.042
PBG Post-test versus Pre-test	32	.125	.275 (31)	.785
CG Post-test versus Pre-test	32	–.094	–.407 (31)	.687

For the deductive-reasoning skill combined direct and transfer learning scores, post-hoc Tukey's HSD tests showed that the CG scored significantly higher than the ESG ($p = .014$) on the pre-test while there were no significant pre-test score differences between the PBG and the CG or between the ESG and the PBG. An ANCOVA, using the CG pre-test scores as a covariate, showed no significant differences between the groups. Given the CG scored significantly higher than the ESG, a Pearson's correlation coefficient was calculated. The correlation between the pre-test and post-test score was significant; $r(95) = .394$, $p = .000$. Given a significant Pearson's correlation, a paired samples t-test was calculated to assess whether there were significant differences between the pre-test and post-test scores for each group. Based on the t-test results for the deductive-reasoning skill combined direct and transfer learning scores, as summarized in Table 4.2, the ESG score was significantly higher on the post-test than the pre-test ($p = .042$). The PBG did not have a significant difference between its pre-test and post-test scores.

4.2.2 Direct Learning

Table 4.3

Pre-test and Post-test (df=2,93) Direct Learning Scores

Test	ESG N=32 Mean (SD)	PBG N=32 Mean (SD)	CG N=32 Mean (SD)	F	p	Tukey HSD Test
Pre-test Total	28.19 (7.15)	29.28 (7.17)	28.84 (6.63)	.199	.820	
Post-test Total	33.55 (4.63)	34.14 (4.95)	29.11 (6.65)	8.03	.001	ESG > CG PBG > CG
Classification Skill Pre-test	5.63 (2.43)	5.38 (2.37)	5.16 (2.38)	.307	.736	
Classification Skill Post-test	6.63 (0.91)	6.66 (1.21)	5.31 (2.24)	7.76	.001	ESG > CG PBG > CG
Analogical-reasoning Skill Pre-test	5.47 (1.80)	5.69 (1.67)	5.50 (1.68)	.152	.860	
Analogical-reasoning Skill Post-test	6.84 (1.05)	7.16 (0.81)	5.94 (1.72)	8.16	.001	ESG > CG PBG > CG
Sequencing Skill Pre-test	7.34 (1.56)	7.41 (1.97)	7.00 (1.92)	.461	.632	
Sequencing Skill Post-test	7.94 (1.39)	7.83 (1.39)	6.71 (2.13)	5.30	.007	ESG > CG PBG > CG
Patterning Skill Pre-test	3.78 (1.95)	3.84 (2.16)	3.81 (1.93)	.008	.992	
Patterning Skill Post-test	5.04 (1.62)	5.28 (2.23)	3.97 (2.04)	3.98	.022	PBG > CG
Deductive-reasoning Skill Pre-test	5.97 (3.02)	6.97 (1.99)	7.38 (0.98)	3.58	.032	CG > ESG
Deductive-reasoning Skill Post-test	7.11 (1.59)	7.21 (1.17)	7.19 (1.15)	.056	.945	

To assess whether the above results were different for direct learning, further analysis was done. Table 4.3 presents the pre-test and post-test One-Way ANOVA results from comparing the three groups (ESG, PBG, and CG) on the direct learning scores from the total of the five tests combined as well as the individual test for each specific logical-thinking skill.

For the total direct learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .005$) and the PBG scored significantly higher than the CG ($p = .001$). There were no significant differences between the ESG and the PBG.

For the classification skill direct learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .003$) and the PBG scored significantly higher than the CG ($p = .002$). There were no significant differences between the ESG and the PBG.

For the analogical-reasoning skill direct learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .014$) and the PBG scored significantly higher than the CG ($p = .001$). There were no significant differences between the ESG and the PBG.

For the sequencing skill direct learning scores, post-hoc Tukey's HSD tests showed that the ESG scored significantly higher than the CG ($p = .012$) and the PBG scored significantly higher than the CG ($p = .023$). There were no significant differences between the ESG and the PBG.

For the patterning skill direct learning scores, post-hoc Tukey's HSD tests showed that the PBG scored significantly higher than the CG ($p = .025$). There were no significant differences between the ESG and the CG or between the ESG and the PBG.

Table 4.4

Deductive-reasoning Skill Direct Learning Scores T-test Results

Test	n	Mean difference (Post–Pre)	t (df)	p
ESG Post-test versus Pre-test	32	1.14	2.31 (31)	.028
PBG Post-test versus Pre-test	32	.245	.665 (31)	.511
CG Post-test versus Pre-test	32	–.188	–.882 (31)	.385

For the deductive-reasoning skill direct learning scores, post-hoc Tukey's HSD tests showed that the CG scored significantly higher than the ESG ($p = .029$) on the pre-test while there were no significant pre-test score differences between the PBG and the CG or between the ESG and the PBG. An ANCOVA, using the CG pre-test scores as a covariate, showed no significant differences between the groups. Given the CG scored significantly higher than the ESG, a Pearson's correlation coefficient was calculated. The correlation between the pre-test and post-test score was significant; $r(95) = .687$, $p = .000$. Given a significant Pearson's correlation, a paired samples t-test was calculated to assess whether there were significant differences between the pre-test and post-test scores for each group. Based on the t-test results for the deductive-reasoning skill direct learning scores, as summarized in table 4.4, the ESG score was significantly higher on the post-test than the pre-test ($p = .028$). Both the PBG and CG did not have a significant difference between their pre-test and post-test scores.

4.2.3 ESG Amount of Learning

Table 4.5

ESG Amount of Learning

Test	Post-test n=32 df=1,31 Mean (SD)	Pre-test n=32 df=1,31 Mean (SD)	t	p	Percent Gain
Total Combined Direct and Transfer Learning	39.54 (6.06)	33.09 (8.71)	5.36	.000	19.5%
Classification Skill - Direct and Transfer Learning	7.81 (1.31)	6.44 (2.65)	2.78	.009	27.2%
Analogical-reasoning Skill - Direct and Transfer Learning	8.68 (1.23)	7.06 (2.20)	5.00	.000	22.9%
Sequencing Skill - Direct and Transfer Learning	8.47 (1.65)	7.72 (1.80)	3.41	.002	9.7%
Patterning Skill - Direct and Transfer Learning	6.15 (1.90)	4.72 (2.26)	3.16	.004	30.4%
Deductive-reasoning Skill - Direct and Transfer Learning	8.43 (2.03)	7.16 (3.69)	2.12	.042	17.8%
Total Direct Learning	33.55 (4.63)	28.19 (7.15)	5.20	.000	19.0%
Classification Skill - Direct Learning	6.63 (0.91)	5.63 (2.43)	2.31	.028	17.8%
Analogical-reasoning Skill - Direct Learning	6.84 (1.05)	5.47 (1.80)	4.67	.000	25.1%
Sequencing Skill - Direct Learning	7.94 (1.39)	7.34 (1.56)	3.05	.005	8.1%
Patterning Skill - Direct Learning	5.04 (1.62)	3.78 (1.95)	3.08	.004	33.2%
Deductive-reasoning Skill - Direct Learning	7.11 (1.59)	5.97 (3.02)	2.31	.028	19.1%

Table 4.5 presents the paired samples t-test results from comparing the ESG pre-test and post-test total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, total direct learning scores, and the direct learning scores on each specific logical-thinking skill.

For the ESG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, total direct learning scores, and direct learning scores on each specific logical-thinking skill, there was a significant percentage gain in every pre-test to post-test score.

4.2.4 PBG Amount of Learning

Table 4.6

PBG Amount of Learning

Test	Post-test n=32 df=1,31 Mean (SD)	Pre-test n=32 df=1,31 Mean (SD)	t	p	Percent Gain
Total Combined Direct and Transfer Learning	40.43 (6.34)	34.38 (8.78)	5.90	.000	17.6%
Classification Skill - Combined Direct and Transfer Learning	7.88 (1.60)	6.03 (2.74)	4.43	.000	30.6%
Analogical-reasoning Skill - Combined Direct and Transfer Learning	9.06 (0.91)	7.19 (2.01)	5.92	.000	26.1%
Sequencing Skill - Combined Direct and Transfer Learning	8.47 (1.70)	7.75 (2.06)	2.24	.033	9.3%
Patterning Skill - Combined Direct and Transfer Learning	6.28 (2.64)	4.78 (2.47)	3.36	.002	31.3%
Deductive-reasoning Skill - Combined Direct and Transfer Learning	8.75 (1.54)	8.63 (2.52)	.28	.785	1.4%
Total Direct Learning	34.14 (4.95)	29.28 (7.17)	5.60	.000	16.6%
Classification Skill - Direct Learning	6.66 (1.21)	5.38 (2.37)	3.65	.001	23.8%
Analogical-reasoning Skill - Direct Learning	7.16 (0.81)	5.69 (1.67)	5.31	.000	25.8%
Sequencing Skill - Direct Learning	7.83 (1.39)	7.41 (1.97)	1.30	.204	5.8%
Patterning Skill - Direct Learning	5.28 (2.23)	3.84 (2.16)	3.55	.001	37.3%
Deductive-reasoning Skill - Direct Learning	7.21 (1.17)	6.97 (1.99)	.67	.511	3.5%

Table 4.6 presents the paired samples t-test results from comparing the PBG pre-test and post-test total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, total direct learning scores, and the direct learning scores on each specific logical-thinking skill.

For the PBG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on the classification, analogical-reasoning, sequencing, and patterning skills, total direct learning scores, and direct learning scores on the classification, analogical-reasoning, and patterning skills, there was a significant percentage gain in pre-test to post-test scores. There was no significant pre-test to post-test change in the combined direct and transfer learning on the deductive-reasoning skill, direct learning on the sequencing skill, and direct learning on the deductive-reasoning skill.

4.2.5 CG Amount of Learning

Table 4.7

CG Amount of Learning

Test	Post-test n=32 df=1,31 Mean (SD)	Pre-test n=32 df=1,31 Mean (SD)	t	p	Percent Gain
Total Combined Direct and Transfer Learning	34.29 (8.21)	33.88 (8.04)	.81	.422	1.2%
Classification Skill - Combined Direct and Transfer Learning	6.19 (2.71)	5.81 (2.78)	1.79	.083	6.5%
Analogical-reasoning Skill - Combined Direct and Transfer Learning	7.45 (2.17)	6.97 (2.22)	1.90	.067	6.9%
Sequencing Skill - Combined Direct and Transfer Learning	7.16 (2.44)	7.28 (2.20)	-.49	.627	-1.6%
Patterning Skill - Combined Direct and Transfer Learning	4.52 (2.43)	4.75 (2.26)	-.67	.510	-4.9%
Deductive-reasoning Skill - Combined Direct and Transfer Learning	8.97 (1.43)	9.06 (1.24)	-.41	.687	-1.0%
Total Direct Learning	29.11 (6.65)	28.84 (6.63)	.56	.579	0.9%
Classification Skill - Direct Learning	5.31 (2.24)	5.16 (2.38)	.76	.455	3.0%
Analogical-reasoning Skill - Direct Learning	5.94 (1.72)	5.50 (1.68)	1.91	.065	7.9%
Sequencing Skill - Direct Learning	6.71 (2.13)	7.00 (1.92)	-1.36	.183	-4.1%
Patterning Skill - Direct Learning	3.97 (2.04)	3.81 (1.93)	.55	.589	4.0%
Deductive-reasoning Skill - Direct Learning	7.19 (1.15)	7.38 (0.98)	-.88	.385	-2.5%

Table 4.7 presents the paired samples t-test results from comparing the CG pre-test and post-test total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, total direct learning scores, and the direct learning scores on each specific logical-thinking skill.

For the CG students, there was no significant pre-test to post-test change in the total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking skill, direct learning total scores, or direct learning scores on each logical-thinking skill.

4.3 Research Questions 5, 6, and 7

5. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?
6. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?
7. Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

4.3.1 Total Transfer Learning

Table 4.8

Total Transfer Learning Scores

Test	ESG n=32 Mean (SD)	PBG n=32 Mean (SD)	CG n=32 Mean (SD)	df	F	p	Tukey HSD Test
Pre-test	4.91 (1.86)	5.09 (1.87)	5.03 (1.73)	(2,93)	.088	.916	
Post-test	6.00 (1.76)	6.29 (1.74)	5.18 (1.92)	(2,93)	3.28	.042	PBG > CG

Table 4.8 presents the One-Way ANOVA results from comparing the three groups (ESG, PBG, and CG) on the pre-test and post-test transfer learning scores from the total of the five specific logical-thinking skill tests.

For the total transfer learning scores, post-hoc Tukey's HSD tests showed that the PBG scored significantly higher than the CG ($p = .042$). There were no significant differences between the ESG and the CG or between the ESG and the PBG.

Table 4.9

Total Amount of Transfer Learning

Group	Post-test n=32 df=1,31 Mean (SD)	Pre-test n=32 df=1,31 Mean (SD)	t	p	Percentage Gain
ESG	6.00 (1.76)	4.91 (1.86)	3.61	.001	22.2%
PBG	6.29 (1.74)	5.09 (1.87)	4.38	.000	23.6%
CG	5.18 (1.92)	5.03 (1.73)	.62	.541	2.9%

Table 4.9 presents the paired samples t-test results from comparing the pre-test and post-test total transfer learning scores for each group.

With respect to transfer learning for the ESG students, there was a significant percentage gain in learning between the pre-test and post-test on the total transfer learning scores ($p = .001$).

In regards to transfer learning for the PBG students, there was a significant percentage gain in learning between the pre-test and post-test on the total transfer learning scores ($p = .000$).

With respect to transfer learning for the CG students, there was no significant change in learning between the pre-test and post-test on the total transfer learning scores.

4.4 Test Reliability

Table 4.10

Test Reliability

Test	Number of items	Cronbach's alpha
Total Pre-test Combined Direct and Transfer Learning	50	.90
Total Pre-test Direct Learning	41	.88
Total Post-test Combined Direct and Transfer Learning	50	.89
Total Post-test Direct Learning	41	.87
Total Pre-test Transfer Learning	9	.60
Total Post-test Transfer Learning	9	.66
Classification Skill Pre-test Combined Direct and Transfer Learning	10	.83
Classification Skill Pre-test Direct Learning	8	.81
Classification Skill Post-test Combined Direct and Transfer Learning	10	.77
Classification Skill Post-test Direct Learning	8	.75
Analogical-reasoning Skill Pre-test Combined Direct and Transfer Learning	10	.71
Analogical-reasoning Skill Pre-test Direct Learning	8	.61
Analogical-reasoning Skill Post-test Combined Direct and Transfer Learning	10	.73
Analogical-reasoning Skill Post-test Direct Learning	8	.70
Sequencing Skill Pre-test Combined Direct and Transfer Learning	10	.72
Sequencing Skill Pre-test Direct Learning	9	.70
Sequencing Skill Post-test Combined Direct and Transfer Learning	10	.76
Sequencing Skill Post-test Direct Learning	9	.73
Patterning Skill Pre-test Combined Direct and Transfer Learning	10	.71
Patterning Skill Pre-test Direct Learning	8	.68
Patterning Skill Post-test Combined Direct and Transfer Learning	10	.67
Patterning Skill Post-test Direct Learning	8	.61

Table 4.10, continued

Deductive-reasoning Skill Pre-test Combined Direct and Transfer Learning	10	.91
Deductive-reasoning Skill Pre-test Direct Learning	8	.91
Deductive-reasoning Skill Post-test Combined Direct and Transfer Learning	10	.69
Deductive-reasoning Skill Post-test Direct Learning	8	.74

Table 4.10 presents the reliability statistics for internal consistency as determined through calculating Cronbach's alpha for both the pre-test and post-test for the total combined direct and transfer learning, total direct learning, and total transfer learning, and, for each specific logical-thinking skill, the combined direct and transfer learning, and direct learning. Internal consistency of the test ranged from excellent to questionable, where Cronbach alpha values ≥ 0.9 are excellent, ≥ 0.8 and < 0.9 are good, ≥ 0.7 and < 0.8 are acceptable, ≥ 0.6 and < 0.7 are questionable, ≥ 0.5 and < 0.6 are poor, and $< .5$ are unacceptable (Gliem & Gliem, 2003; Mayrath, 2009).

4.4.1 Comments Regarding the Internal Consistency

The internal consistency of the tests for research questions 2, 3, and 4 ranged from excellent to questionable. Cronbach alpha values were between 0.91 and 0.61.

In general, for the total combined direct and transfer learning scores, combined direct and transfer learning scores on each test, total direct learning scores, and direct learning scores on each test, internal consistency was either good or excellent as Cronbach's alpha ranged from 0.87 to 0.90. These tests contained between 41 and 50 questions.

In general, for the combined direct and transfer learning scores and the direct learning scores on the specific test for each logical-thinking skill, internal consistency ranged from questionable to excellent as Cronbach alpha values were as low as 0.61 and

as high as 0.91. A factor in the lower values was that these tests only contained between 8 and 10 questions.

Cronbach's alpha for each patterning skill test may have been impacted by the test being comprised of five unrelated kinds of patterns (facial characteristics, letters, integers and fractions, geometric shapes, and lines).

Cronbach's alpha for the deductive-reasoning skill post-test for the combined direct and transfer learning (0.69) may have been affected by the students in the paper-based group as it seemed that they felt overwhelmed by the activity and did not appear to try hard, according to the teacher supervising the students. The intervention was 159 pages long (D. Moore, personal communication, May 12, 2009).

The internal consistency with respect to the transfer of learning test was questionable. Cronbach's alpha was 0.60 for the pre-test and 0.66 on the post-test. The internal consistency was low because the transfer learning test was comprised of only nine questions from five subscales (two classification, two analogical reasoning, one sequencing, two patterning, and two deductive-reasoning skill questions).

4.5 Summary

This fourth chapter, the findings, provided the findings from the analysis for each of the research questions.

Research question 1: Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?

After all of the changes were put in based on the information gained from the pilot students and the feedback from the iterative reviews of the reviewers until no further changes were requested, it was interpreted that the reviewers considered that the events of instruction utilized in this intervention provided the attributes needed for the

instructional interventions to effectively teach the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

Research question 2: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?

There were no significant differences between the ESG and PBG on any score of any test.

Research question 3: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?

For the total combined direct and transfer learning post-test scores, the ESG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the ESG scored significantly higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the CG scored significantly higher than the ESG on the pre-test. However, for the deductive-reasoning skills test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test. The CG did not have a significant difference between its pre-test and post-test scores.

For the total direct learning scores, the ESG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, and sequencing skills, the ESG scored significantly higher than the CG. For the patterning skill direct learning scores, there were no significant differences between the ESG and the CG. For the deductive-reasoning skill direct learning scores, the CG scored significantly higher than the ESG on the pre-test. However, for the deductive reasoning

test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test. Similarly for the patterning skill test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test.

Research question 4: Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?

For the total combined direct and transfer learning post-test scores, the PBG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

For the total direct learning scores, the PBG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill direct learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

Other findings for research questions 2, 3, and 4:

There were other findings for research questions 2, 3, and 4 based on paired samples t-test results from comparing the pre-test and post-test scores on each test.

For the ESG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on each logical-thinking skill, total direct learning scores, and direct learning scores on each logical-thinking skill, there was a significant percentage gain in every pre-test to post-test score.

For the PBG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on each logical-thinking skill, total direct learning scores, and direct learning scores on each logical-thinking skill, there was a significant percentage gain in every pre-test to post-test score, except there was no significant percentage gain in the combined direct and transfer learning on the deductive-reasoning skill, direct learning on the sequencing skill, and direct learning on the deductive-reasoning skill.

For the CG students, there was no significant pre-test to post-test change in the total combined direct and transfer learning scores, combined direct and transfer learning scores on each logical-thinking skill, direct learning total scores, or direct learning scores on each logical-thinking skill.

The internal consistency of the tests for research questions 2, 3, and 4 ranged from excellent to questionable. Cronbach alpha values were between 0.91 and 0.61.

Research question 5: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?

There were no significant differences between the ESG and PBG.

Research question 6: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?

For the total transfer learning scores, there were no significant differences between the ESG and the CG.

Research question 7: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

For the total transfer learning scores, the PBG scored significantly higher than the CG.

Other findings for research questions 5, 6, and 7:

There were other findings for research questions 5, 6, and 7 based on the paired samples t-test results from comparing the pre-test and post-test total transfer learning scores for each group. Both the ESG and PBG students had a significant percentage gain in the ability to transfer learning. The CG students had no significant percentage gain in the ability to transfer learning.

The internal consistency with respect to the transfer of learning test was questionable. Cronbach's alpha was 0.60 for pre-test and 0.66 on the post-test.

Chapter 5

Discussion and Conclusions

5.0 Introduction

This chapter summarizes the main findings for each research question, discusses the findings of each research question in detail, states implications of the research, addresses limitations of the study, gives suggestions for further research, and finishes with a conclusion.

To achieve the objectives of this research, seven research questions were written to guide the study. To answer these research questions, a mixed-method research design was adopted. A qualitative assessment was conducted to ascertain the appropriateness of the materials and a quantitative assessment was done using a pre-test, post-test, experimental design to assess the effectiveness of the materials in teaching the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

5.1 Summary of the Main Findings

The main findings of each research question, based on the analysis in chapter 4, are stated below.

5.1.1 Main Findings for Research Question 1

Research Question 1: Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?

To answer this research question, a qualitative study was conducted to ensure as much feedback as possible was received from the reviewers on the instructional design of the educational-software and paper-based resources, as recommended by Kingston (2011) and Legant (2010). The instructional design and qualitative assessment were based on Gagné's Nine Events of Instruction. Specifically, the intent was for the provided feedback to improve the materials so that the attributes of Gagné's Nine Events of Instruction were present so that the educational-software and paper-based materials would effectively teach logical-thinking skills to grade six and seven students. Feedback from six pilot students was also used to revise the materials.

The main finding was that, after the materials were adjusted based on the information gleaned from the pilot students and the changes put in as suggested by the reviewers until no further changes were recommended, it was reasoned that the reviewers considered that the events of instruction addressed in this intervention (gaining attention, informing the learner of the learning outcome, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer) provided the attributes needed for the instructional interventions to effectively teach the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

5.1.2 Main Findings for Research Questions 2, 3, and 4

For this quantitative analysis, one-way ANOVAs were performed to compare the three groups. If significance was found between the groups, a Tukey HSD Post Hoc Test was done. As well, paired samples t-tests were calculated to assess whether there was a significant difference between the pre-test and post-test scores for each group.

Research Question 2: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?

Using ANOVA and Tukey HSD Post Hoc Test calculations, there were no significant differences between the ESG and PBG on any score of any test.

Based on paired samples t-test results that compared the pre-test and post-test scores, for the ESG students' total combined direct and transfer learning scores, combined direct and transfer learning scores for each specific logical-thinking test, total direct learning scores, and direct learning scores for each specific logical-thinking test, there was a significant percentage gain in every pre-test to post-test comparison.

Based on paired samples t-test results from comparing the pre-test and post-test scores, for the PBG students' total combined direct and transfer learning scores, combined direct and transfer learning scores for each specific logical-thinking test, total direct learning scores, and direct learning scores for each specific logical-thinking test, there was a significant percentage gain in every pre-test to post-test comparison, except there was no significant percentage gain in the combined direct and transfer learning on the deductive-reasoning skill, direct learning on the sequencing skill test, and direct learning on the deductive-reasoning skill.

Research Question 3: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?

Based on ANOVA and Tukey HSD Post Hoc Test calculations, for the total combined direct and transfer learning scores, the ESG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the ESG scored significantly

higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the CG scored significantly higher than the ESG on the pre-test. For the deductive reasoning test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test.

Through ANOVA and Tukey HSD Post Hoc Test calculations, for the total direct learning scores, the ESG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, and sequencing skills, the ESG scored significantly higher than the CG. For the patterning skill direct learning scores, there were no significant differences between the ESG and the CG. For the deductive-reasoning skill direct learning scores, the CG scored significantly higher than the ESG on the pre-test. For the deductive reasoning test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test. Similarly for the patterning skill test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test.

Based on paired samples t-test results from comparing the pre-test and post-test scores, for the CG students, there was no significant pre-test to post-test change in the total combined direct and transfer learning scores, combined direct and transfer learning scores on each test, direct learning total scores, or direct learning scores on each specific logical-thinking skill test. This is in contrast to the ESG students, who had a significant percentage gain in each test, as stated above within the main findings for research question 2.

Research Question 4: Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?

Using ANOVA and Tukey HSD Post Hoc Test calculations, for the total combined direct and transfer learning, the PBG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

Based on ANOVA and Tukey HSD Post Hoc Test calculations, for the total direct learning scores, the PBG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill direct learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

As stated above within the main findings for research questions 2 and 3, based on paired samples t-test results, the PBG had a significant percentage gain in every pre-test to post-test scores except on three specific logical-thinking skill tests while the CG had no significant change in any pre-test to post-test score.

5.1.3 Main Findings for Research Questions 5, 6, and 7

For this quantitative analysis, one-way ANOVAs were performed to compare the three groups. If significance was found between the groups, a Tukey HSD Post Hoc Test was done. As well, paired samples t-tests were calculated to assess whether there was a significant difference between the pre-test and post-test scores for each group.

Research Question 5: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?

Through ANOVA and Tukey HSD Post Hoc Test calculations, there were no significant differences between the ESG and PBG.

Based on paired samples t-test results from comparing the pre-test and post-test scores, both the ESG and PBG students had a significant percentage gain in the ability to transfer learning.

Research Question 6: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?

Using ANOVA and Tukey HSD Post Hoc Test calculations, for the total transfer learning scores, there were no significant differences between the ESG and the CG.

Through paired samples t-test results from comparing the pre-test and post-test scores, the ESG students had a significant percentage gain in the ability to transfer learning and the CG students had no significant change in the ability to transfer learning.

Research Question 7: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

Based on ANOVA and Tukey HSD Post Hoc Test calculations, for the total transfer learning scores, the PBG scored significantly higher than the CG.

Using paired samples t-test results, the PBG students had a significant percentage gain in the ability to transfer learning and the CG students had no significant change in the ability to transfer learning.

5.2 Discussion of the Findings

This research led to the development of instructional materials that aimed to teach specific logical-thinking skills and the assessment of whether the instructional

materials could effectively teach those skills. This section presents a discussion on the findings for each research question.

5.2.1 Discussion Regarding Research Question 1

Research Question 1: Did the educational software and paper-based materials have the attributes to teach logical-thinking skills?

Based on the qualitative analysis, after the initial materials were modified through the information gained from the pilot students and the changes put in as suggested by the reviewers based on their iterative reviews of the materials until no further suggestions were given, it was determined that the reviewers considered that the events of instruction addressed in this intervention (gaining attention, informing the learner of the learning outcome, presenting the material, providing learning guidance, eliciting the performance, providing feedback, assessing performance, and enhancing retention and transfer) provided the attributes needed for the instructional interventions to effectively teach the logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning.

It was expected that the reviewers would think that the instructional materials had the attributes needed to teach the logical-thinking skills. This was expected because the Combined Instructional Design and Development Model that was used as a foundation to create the interventions was based on a nonlinear variation of the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional development cycle model, a variation of Dick and Carey's (1990) systematic instructional design process, and Gagné's Nine Events of Instruction, and the reviewers were involved throughout the design and development of the instructional materials.

The ADDIE model is reputed to be effective for developing solutions for many instructional problems (Dunning, 2008; Fenrich, 2014; Parsons, 2008; Reddy, 2008;

Singh, 2009). However, Dunning (2008), Fenrich (2014), Parsons, (2008), and Singh (2009) suggest that, rather than being restricted by exactly following the ADDIE model, the ADDIE model should be adapted as needed to create effective materials. For this research, a nonlinear model was followed to enable iterative evaluation and revision throughout the instructional design and development process.

Yet, adhering to an instructional development cycle does not in itself lead to successful instructional materials, in that instructional development cycle models do not state the specific steps needed to design instructional materials. Within the instructional development cycle, a systematic process of instructional design should be followed to help ensure that essential steps are performed. However, the systematic process is general and does not specify the attributes needed for instructional interventions to be effective (Fenrich, 2014).

The specific design of the instructional interventions of this research was based on Gagné's Nine Events of Instruction. Gagné's Nine Events of Instruction provide the specific attributes that need to be designed into instructional materials for effective learning to occur (Fenrich, 2014; Gagné et al., 1988; Maryannakis, 2009). Nonetheless, following Gagné's Events of Instruction does not in itself ensure that higher-order thinking skills are learned. Pond (1987) used Gagné's Nine Events of Instruction as a basis for creating instructional materials and found that the learners' critical-thinking ability was not enhanced through an educational-software intervention. In contrast, Tilson's (1986) interventions, which were based on Gagné's Nine Events of Instruction, led to gains in critical-thinking skills. Quality instructional design is a foundation for effective instructional materials as flaws in instructional design will compromise learning (Fenrich, 2014). The reviewers iteratively checking the materials helped to ensure effective instructional design.

The reviewers were involved throughout the design and development of the instructional materials. Their comments and suggestions led to the development of the learning outcomes, the design of the corresponding instructional strategies, and continued revisions of the materials, until no further feedback was needed. The involvement of reviewers in content development can lead to their assumption that the materials have the attributes to teach effectively since involving teachers in curriculum development has led to teachers being supportive of the resulting products (Bowers, 1991; Young, 1988; Oloruntegbe, 2010).

In general, the literature supports the qualitative findings of this study where it was interpreted that the reviewers thought that the instructional materials had the attributes needed to teach the logical-thinking skills. Other researchers with similar findings include Duffield (1989), Hugo (1989), Irwin (1995), Lee (2008), Meyer (2010), Morey (2008), and Petris (2009). However, not all researchers have qualitatively found that higher-order thinking skills can be taught. Fanetti (2011) had insignificant qualitative findings. Of the above studies, Duffield, Fanetti, Irwin, Meyer, and Morey's findings regarded educational software, while only Lee's research was based on a paper-based intervention. There were only a few comparable studies in that most of the qualitative research around higher-order thinking skills has been done in traditional classroom settings. Only Fanetti's research was on a type of logical-thinking skill. However, the reasoning skills taught by Fanetti's intervention were different than those of this study and the students were post-secondary students, as opposed to the grade six and seven students of this study.

5.2.2 Discussion Regarding Research Question 2

Research Question 2: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those taught using paper-based materials?

Through ANOVA and Tukey HSD Post Hoc Test calculations, for every test, there were no significant differences between the ESG and PBG. These findings are harmonious with Clark (1983) who stated,

Consistent evidence is found for the generalization that there are no learning benefits to be gained from employing any specific medium to deliver instruction. Research showing performance or time-saving gains from one or another medium are shown to be vulnerable to compelling rival hypotheses concerning the uncontrolled effects of instructional method and novelty (p. 445).

With respect to educational software interventions and in support of Clark, Singh (2010) stated the over the years Clark had “maintained that technology in and of itself cannot improve learning outcomes” (p. 2) over traditionally-delivered content. That is to say, if the content is presented through two modes of delivery that follow the same instructional strategy, the findings should be the same. Similarly, Semper Scott (2005) stated that minor differences in the learning experience do not result in significant differences in performance. In agreement with this research and Clark’s (1983) conclusion, other researchers have also found no significant differences between comparable interventions. These researchers include Cott (1991), Heo (2012), Huff (1998), Larson et al. (2009), Shiah (1994), and Titterington (2007). No studies were found where comparable interventions led to significantly different findings.

5.2.3 Discussion Regarding Research Question 3

Research Question 3: Were there significant differences in the logical-thinking ability between subjects taught using educational software compared to those not being exposed to any intervention?

Through ANOVA and Tukey HSD Post Hoc Test calculations, for the total combined direct and transfer learning post-test scores, the ESG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the ESG scored significantly higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the CG scored significantly higher than the ESG on the pre-test. However, for the deductive reasoning test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test.

Based on ANOVA and Tukey HSD Post Hoc Test calculations, for the total direct learning scores, the ESG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, and sequencing skills, the ESG scored significantly higher than the CG. For the patterning skill direct learning scores, there were no significant differences between the ESG and the CG. For the deductive-reasoning skill direct learning scores, the CG scored significantly higher than the ESG on the pre-test. However, for the deductive reasoning test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test. Similarly for the patterning skill test, a paired samples t-test showed that the ESG score was significantly higher on the post-test than the pre-test.

With respect to logical-thinking skills, as were taught in the interventions of this study, other researchers have also quantitatively found at least some significant gains with stand-alone educational software. These researchers include Chapman (1985),

Collins (1984), Cousins and Ross (1993), Fenrich (2002), Grossen (1988), Hurst and Milkent (1994), Larson et al. (2009), Mayes (1995), Raidl (1993), Robertson (2005), Stratton (2003), Swan (1990), and Toth (1996). However, in comparison to this study, none of these researchers assessed the same logical-thinking skills and none of the studies only included grade six and seven students.

In this study, as compared to the CG, the ESG did not gain a significant amount of deductive-reasoning skill based on the combined direct and transfer learning score and the direct learning score. In both cases, this was likely affected by the CG scoring significantly higher than the ESG on the corresponding pre-test of the deductive reasoning test. Significant ESG deductive-reasoning skill gains were shown through paired samples t-test results. The ESG pre-test to post-test combined direct and transfer learning score was significantly improved (a 17.8% gain) while the CG pre-test to post-test score was insignificantly different (a 1.0% decrease). Also, the ESG pre-test to post-test direct learning score was significantly improved (a 19.1% gain) while the CG pre-test to post-test score was insignificantly different (a 2.5% decrease). As stated above, these pre-test to post-test gains are compatible with the findings of other researchers.

For the patterning skill direct learning scores, there were no significant differences between the ESG and the CG. Since there was a significant difference between the ESG and CG in the combined direct and transfer learning scores, the ESG post-test direct learning scores are significantly improved over pre-test scores, and the CG pre-test and post-scores are insignificantly different, the lack of a significant difference between the ESG and CG may have been due to only having eight questions on the pre-test and post-test in that the probability of finding a difference would have increased if the number of test questions increased (Lee, 2008; Phillips, 2005).

5.2.4 Discussion Regarding Research Question 4

Research Question 4: Were there significant differences in the logical-thinking ability between subjects taught using paper-based materials compared to those not being exposed to any intervention?

Based on ANOVA and Tukey HSD Post Hoc Test calculations, for the total combined direct and transfer learning post-test scores, the PBG scored significantly higher than the CG. For the combined direct and transfer learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill combined direct and transfer learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

Through ANOVA and Tukey HSD Post Hoc Test calculations, for the total direct learning scores, the PBG scored significantly higher than the CG. For the direct learning scores for the classification, analogical-reasoning, sequencing, and patterning skills, the PBG scored significantly higher than the CG. For the deductive-reasoning skill direct learning scores, the PBG and CG did not have a significant difference between their pre-test and post-test scores.

Like the ESG, the PBG did not gain a significant amount of deductive-reasoning skill based on the combined direct and transfer learning score as compared to the CG. Similarly, the PBG did not gain a significant amount of deductive-reasoning skill based on the direct learning score as compared to the CG. This may have been due to the PBG being overwhelmed with the amount of material and becoming tired due to the amount of reading. The students seemed to lose their concentration about halfway through the intervention. The intervention was 159 pages of double-sided printing, which was far thicker than typical assignments (D. Moore, personal communication, May 12, 2009).

The PBG may have lost their motivation to work through the materials (Baker & Wigfield, 2011; Barns & Monroe, 2011; Fenrich, 2014). A lack of motivation is consistent with the results where the PBG and CG pre-test to post-test combined direct and transfer learning score changes were insignificant (respectively a 1.4% gain and a 1.0% decrease) and the PBG and CG pre-test to post-test direct learning score changes were also insignificant (respectively a 3.5% gain and a 2.5% decrease), whereas the ESG had significant gains (respectively a 17.8% and 19.1% gain) with comparable materials, based on paired samples t-test results. In stand-alone educational software interventions, the amount of content is not as readily apparent as with paper-based materials where learners can visually see the thickness of the handout.

With respect to logical-thinking skills taught through paper-based materials, two researchers also quantitatively found some significant gains with paper-based materials. These were Larson et al. (2009), and Titterington (2007). However, in comparison to the interventions of this study, neither of these researchers assessed the same logical-thinking skills and neither of the studies only included grade six and seven students. As well, Titterington's intervention was not stand-alone in that traditional delivery methods were also a part of the intervention.

5.2.5 Discussion Regarding Gains in Amount Learned

For each group, a paired samples t-test result was obtained from comparing the pre-test and post-test scores on each test.

For the ESG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on each test, total direct learning scores, and direct learning scores on each test, there was a significant percentage gain in every pre-test to post-test score.

For the PBG students' total combined direct and transfer learning scores, combined direct and transfer learning scores on each test, total direct learning scores, and direct learning scores on each test, there was a significant percentage gain in every pre-test to post-test score, except there was no significant change in the deductive-reasoning skill, as discussed above, and direct learning on the sequencing skill test. For the sequencing skill, since there was a significant difference between the PBG and CG in the total combined direct and transfer learning scores and the total direct learning scores, the PBG post-test combined direct learning and transfer score is significantly higher than the pre-test score, and the CG pre-test and post-scores are insignificantly different, significant gains were expected. The lack of a significant difference between the PBG and CG could have been affected by a ceiling effect. For the direct learning pre-test scores, the mean PBG score was 7.41 out of 9. Consequently, the lack of significant differences may have been due to a ceiling effect where there was not enough room for significant improvement to be shown in the experimental group (Jensen, 2008; McNamee, 2011). As well, the lack of a significant difference between the PBG and CG may have been due to only having nine questions on the pre-test and post-test in that the probability of finding a difference would have increased if the number of test questions was increased (Lee, 2008; Phillips, 2005).

For the CG students, there was no significant pre-test to post-test change in the total combined direct and transfer learning scores, combined direct and transfer learning scores on each specific logical-thinking test, direct learning total scores, and direct learning scores on each specific logical-thinking test.

In general, both the educational-software and paper-based interventions led to significant gains in logical-thinking ability. With respect to the significant pretest posttest gains found from the total combined direct and transfer learning scores and the

total direct learning scores, these findings are consistent with other researchers who reported quantitative findings that learners could be taught a significant amount of higher-order thinking skills (Abdellatif, 2008; Allison, 1993; Bachann, 1995; Bradberry-Guest, 2011; Brown, 2000; Burkhart, 2006; Campbell, 2000; Carwie, 2010; Chapman, 1985; Collins, 1984; Cotton, 1991; Cousins & Ross, 1993; Crone-Todd, 2002; Duffield, 1989; Etsey, 2004; Fenrich, 2002; Galinski, 1988; Grossen, 1988; Hendricks, 1998; Huff-Benkoski, 1998; Hurst & Milkent, 1994; Johnson, 1997; Judy, 1987; Kaplan, 1997; Katzlberger, 2006; Kreyche, 2002; Larson et al., 2009; Leiker, 1993; Lewis, 1998; Mayes, 1995; McMillen, 2008; Orabuchi, 1992; Phillips, 1992; Pogrow, 2005; Powell-Laney, 2010; Raidl, 1993; Reed, 1999; Robertson, 2005; Ruzhitskaya, 2012; Shiah, 1994; Shinnick, 2010; Sondel, 2009; Stratton, 2003; Svenningsen, 2009; Swan, 1990; Tarkington, 1988; 1999a; Tilson, 1986; Titterington, 2007; Toth, 1996; Webb, 1997; Wilson, 1986; Wu, 2009).

In this study, there were significant differences in the total combined direct and transfer learning scores and the total direct learning scores. However, the findings were not significant in a few of the tests for specific logical-thinking skills. Lee (2008) had similar findings where there was a significant difference based on the whole rubric but no significant differences in critical thinking based on some individual rubric items. Mixed findings are consistent with other researchers. These researchers include Campbell (2000), Chapman (1985), Cousins and Ross (1993), Johnson (1997), Kaplan (1997), Mayes (1995), Phillips (1992), Raidl (1993), Robertson (2005), Swan (1990), (1999a), and Toth (1996). Possible explanations for the lack of a significant difference between the experimental groups and control group on specific logical-thinking tests are discussed above.

It was expected that the experimental groups would perform significantly higher on the post-tests as compared to the pre-tests because of the Combined Instructional Design and Development Model followed (as discussed above), the reviewers were engaged throughout the design and development of the instructional materials, it was felt that the reviewers thought that the instructional materials had the attributes needed to teach the logical-thinking skills, and the instructional materials contained many features that support effective teaching.

The reviewers were engaged throughout the design and development of the instructional materials. Their advice led to the development of the learning outcomes, the design of the corresponding instructional strategies, and continued revisions of the materials until no further feedback was needed. Consequently, it was concluded that the reviewers thought that the instructional materials had the attributes needed to teach the logical-thinking skills.

The instructional materials contained many features that support effective teaching. The techniques used to gain and maintain attention included asking the students to obtain high scores, stressing the importance of thinking carefully, posing challenging statements and questions, and making the materials highly interactive. These techniques also helped to motivate the students. The learner was informed of each learning outcome as the learning outcome was directly presented within the instructional materials. The content was matched to the anticipated cognitive development of the students. Consequently, it was expected that the students would have the intellectual skills needed to learn the content. The concepts gradually increased in difficulty in that the material was presented in small incremental steps. This parallels Vygotsky's Zone of Proximal Development learning theory. A variety of instructional activities and strategies were created. The activities supported each learning outcome.

There was a high degree of active learning in the samples, practice questions, self-test, and challenge questions. Active learning is a cornerstone of the constructivist theory of learning. The learner's focus was directed to the deeper learning concepts that supported higher-order thinking skills. For example, this was achieved through the questions asked. The assimilation and accommodation of knowledge into long-term memory was supported. Metacognition and self-reflection were encouraged. There was guidance for how to solve each of the skills through the presentation of the initial samples, and direct statements of what needed to be done to answer the questions. Feedback contained hints with increasing detail and the final elaborative feedback explained why the answer was correct and why other answer choices were incorrect, as was appropriate (Fenrich, 2014; Gagné et al., 1988; Rosenshine, 2012; Solomon, 2008; Wu, 2009).

It was expected that the control group would not have any significant gains because students tend not to improve higher-order thinking skills when there is no explicit intervention in place. This is in agreement with Burkhart (2006), Jeremiah (2012), and Wruck (2010).

5.2.6 Discussion Regarding Research Question 5

Research Question 5: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those taught using paper-based materials?

There were no significant differences between the ESG and PBG.

Given that Clark (1983), Cott (1991), Heo (2012), Huff (1998), Larson et al. (2009), Shiah (1994), and Titterington (2007) found no significant differences between groups taught through comparable interventions, it was not expected that the ESG and PBG would significantly differ in their ability to transfer logical-thinking skills. The

findings of this study are in agreement with these researchers in that there were no significant differences between the ESG and PBG.

5.2.7 Discussion Regarding Research Question 6

Research Question 6: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using educational software compared to those not being exposed to any intervention?

For the total transfer learning scores, there were no significant differences between the ESG and the CG.

These findings match other researchers including Baumer (2009), Duffield (1989), Lafferty (1996), Mayrath (2009), and Meyer (2010). Of these researchers, Baumer, Duffield, Lafferty, Mayrath, and Meyer assessed an educational-software intervention. However, none of these researchers assessed logical-thinking skills or only grade six and seven students. With respect to not finding a significant gain in the ability to transfer logical-thinking skills with the ESG, in contrast, other researchers have found significant gains in the ability of students to transfer logical-thinking skills with an educational-software intervention. These researchers were Fenrich (2002), Grossen (1988), Robertson (2005), and Swan (1990), albeit none of their interventions addressed the same logical-thinking skills or had students who were only in grade six or seven.

Based on the paired samples t-test results from comparing the pre-test and post-test total transfer learning scores for each group, where the ESG had a significant increase in transfer learning associated with a 22.2% gain in score, the PBG also had a significant increase in transfer learning with a 23.6% gain in score, while the CG had no significant increase in transfer learning with a 2.9% gain in score, the lack of a significant difference between the ESG and CG may be due to only having nine questions on the pre-test and post-test. The likelihood of finding a difference would

have increased if the number of test questions was increased (Lee, 2008; Phillips, 2005). Achieving transfer could have been more likely if more explicit and varied examples of transferring the knowledge were provided (Lafferty, 1996). In this study, the number of challenge questions, which were intended to promote the transfer of learning, ranged from three to eight for each of the sub-skills. In contrast, the number of samples and questions designed to teach the logical-thinking skill ranged from 30 to 37. In other words, the emphasis of the interventions was on teaching the skills rather than transferring the skills.

5.2.8 Discussion Regarding Research Question 7

Research Question 7: Were there significant differences in the ability to transfer logical-thinking skills to other problems between subjects taught using paper-based materials compared to those not being exposed to any intervention?

For the total transfer learning scores, the PBG scored significantly higher than the CG.

Other researchers have also found a significant increase in the ability to transfer higher-order thinking skills. These researchers include Fenrich (2002), Grossen (1988), Pogrow (2005), Robertson (2005), and Swan (1990). Of these researchers, Fenrich, Grossen, and Swan assessed logical-thinking skills. However, none of the above researchers' interventions were paper-based, assessed the transfer of the same logical-thinking skills, or assessed only grade six and seven students.

5.2.9 Discussion Regarding Gains in Amount Learned

Based on the paired samples t-test results from comparing the pre-test and post-test total transfer learning scores for each group, with respect to their ability to transfer

learning, both the ESG and PBG students had a significant percentage gain while the CG students did not have a significant percentage gain.

It was expected that both experimental groups would have significantly higher percentage gains in their ability to transfer logical-thinking ability to other problems because of the material's design. The concepts taught were similar to the transfer of learning concepts, as transfer is more readily achieved with near-transfer skills (Meyer, 2010). There was a deliberate effort to transfer the skills, which is necessary for the transfer of skills (Meyer, 2010). The instructional intervention was designed to facilitate the transfer of skills because promoting the transfer of higher-order thinking skills helps transfer occur (Christian, 1995). There was an emphasis on learning the content deeply, which Rocks (2004) stated as being needed for transferring higher-order thinking skills. There was a variety of ways to extensively practice the skills, a strategy recommended by both Hurte (2004) and Lafferty (1996).

5.3 Qualitative Versus Quantitative Findings

This study's objectives were to qualitatively assess the attributes of comparable stand-alone educational-software and paper-based materials that teach logical-thinking skills and quantitatively assess the effectiveness of the educational-software and paper-based materials. As discussed above, the qualitative findings indicated that it was deduced that the reviewers considered that both the educational-software and paper-based materials had the attributes to effectively teach logical-thinking skills. Similarly, as discussed above, the quantitative findings also showed that both of the interventions led to significant gains in logical-thinking skills, although a few of the specific logical-thinking tests did not show significant gains. Duffield (1989) also found significant gains in both the qualitative and quantitative findings with respect to their interventions that taught higher-order thinking skills. Fanetti (2011) had consistent qualitative and

quantitative findings but found no significant differences between the experimental and control groups.

With respect to educational-software interventions, as was one intervention of this study, Duffield (1989) found significant qualitative and quantitative gains while Fanetti (2011) found insignificant qualitative and quantitative gains. No research was found that both qualitatively and quantitatively assessed stand-alone paper-based materials.

In contrast to this study, Meyer (2010), Morey (2008), and Thomson (2009) quantitatively found no significant differences between experimental and control groups but qualitatively found that the interventions led to gains in higher-order thinking skills. Both Meyer and Morey's findings were based on an educational-software intervention. This contradiction between qualitative and quantitative findings can be expected at times because involving subject-matter experts in content development can lead to their belief that their materials have the attributes to teach effectively (Bowers, 1991; Young, 1988; Oloruntegbe, 2010).

5.4 Implications

The objectives of this study were to assess the effectiveness and efficacy of the educational software and paper-based materials. A mixed-method approach was used. The appropriateness of the materials were ascertained qualitatively. Quantitatively, a pre-test post-test experimental design was used to assess the effectiveness of the materials in teaching and transferring logical-thinking skills. A comparison of logical-thinking ability was done between students who were taught through educational software, students who were taught through closely-matched paper-based materials, and a control group participating in unrelated activities. The three groups were also

compared with respect to their logical-thinking ability that was transferred to other problems.

Based on the findings of this study, there are a number of implications:

It is possible to create instructional materials that are considered to have the attributes to teach logical-thinking skills.

The instructional interventions were created through following the Combined Instructional Design and Development Model, which was based on a nonlinear variation of the ADDIE instructional development cycle, a systematic process of instructional design, and Gagné's Nine Events of Instruction. Others can use this model to create interventions that teach logical thinking or other higher-order thinking skills.

The instructional strategies described in this study can be adapted by others to create instructional materials that teach logical-thinking skills. These materials can be used to help solve the problem that many students do not graduate with the higher-order thinking skills needed in the workplace and to function effectively in life.

Logical-thinking skills can be taught through standalone educational-software and paper-based materials. This suggests that other logical-thinking and higher-order thinking skills can be taught through stand-alone educational-software and paper-based materials. Presumably, other stand-alone delivery methods, such as web-based interventions, could also be used to teach logical-thinking and higher-order thinking skills. Given effective instructional design on stand-alone materials, students can learn logical-thinking skills and likely other higher-order thinking skills, whether or not their teachers address the skills or have the ability to teach the skills.

Improving logical-thinking skills needs an explicit intervention in that the control group did not have any significant increase in pre-test to post-test scores in any of the specific logical-thinking skills or logical thinking as a whole (as defined in this

study), whereas both experimental groups gained a significant amount of logical-thinking skills.

Instructional interventions can lead to the near transfer of logical-thinking skills to other problems. This suggests that other interventions can also be designed to promote transfer of learning.

Individuals need an explicit intervention to be able to transfer higher-order thinking skills to new situations since the control group did not have any significant increase in the ability to transfer logical-thinking skills, whereas the group experiencing the paper-based intervention did. As well, both experimental groups had significant percentage gains in their ability to transfer skills and the control group did not.

Designers of paper-based interventions should consider whether the number of pages is appropriate for the intended students given the paper-based group appeared to be overwhelmed with the 159 pages of an intervention and seemed to lose their concentration about halfway through the intervention (D. Moore, personal communication, May 12, 2009). Note that the cost per student for printing that many pages, given the materials can only be used once since learners write their answers on the paper, may not be cost-justifiable over time, especially if the team has the skills and resources to create an educational-software version of the intervention and the students have access to computers.

5.5 Limitations

With respect to this study, there were a number of factors that limit its usefulness:

The instructional interventions were developed through following the created Combined Instructional Design and Development Model. Conducting research using a different instructional design and development model could impact the results.

If this study was to be repeated with different reviewers and a researcher with a different instructional design background, the resulting interventions could look substantially different. Nonetheless, if these individuals followed a similar instructional design and development model and principles of instructional design, the results could be comparable.

For logistical reasons, the researcher was not able to watch every reviewer or pilot student work through the draft materials. Consequently, visual clues, such as a hesitation when working through the materials, could not be noticed and queried with those individuals. The researcher had to assume that the other reviewers' and pilot students' written feedback fully captured their opinions and concerns.

In terms of generalizability, the findings are limited to logical-thinking skills rather than higher-order thinking skills in general. As well, the findings are limited to the five logical-thinking skills of classification, analogical reasoning, sequencing, patterning, and deductive reasoning, as specifically defined, rather than all logical-thinking skills. The findings are also limited to grade six and seven students and near transfer skills rather than far transfer skills.

Internal consistency of the test ranged from excellent to questionable. Consequently, some of the findings should be interpreted with caution.

5.6 Suggestions for Further Research

With respect to further research, a number of studies could contribute to the limited knowledge base regarding the teaching of higher-order thinking skills in a stand-alone mode. Many of the following recommendations are based on the limitations of this study and others are to expand the generalizability of this study's findings.

For grade six and seven learners, develop and assess materials that teach other logical-thinking or higher-order thinking skills. Use the Combined Instructional Design

and Development Model or something comparable as the foundation for creating the materials while adhering to the advice, such as the instructional strategies, contained within the other chapters of this report.

Develop and assess materials that teach logical-thinking or higher-order thinking skills to younger and/or older learners. The age-appropriateness of the materials can be assessed beforehand through reviewer opinions as well as through pilot studies. When doing this with younger learners, determine whether the learners have the maturity to thoroughly complete the tasks. The tasks of the interventions of this study took up to an hour to complete. In general, the grade six and seven students of this study had the maturity to complete the tasks.

Measure attitudes towards the materials before and after the intervention to determine if there is a difference between an educational-software intervention and paper-based materials, particularly when there are larger amounts of content. For example, it may be found that there is an upper limit before learners of a specific age group start to feel overwhelmed by the amount of paper that they have to work through or the amount of time that they can maintain their attention for different types of interventions.

Assess whether gains in logical-thinking skills and the transfer of logical-thinking skills as well as other higher-order thinking skills are maintained over long periods of time. If the gains are lost, determine what can be done to help ensure that the gains are maintained. Some researchers believe that higher-order thinking skills should be emphasized over a long period of time. For example, Clark (2005) stated that taking one course on critical thinking is not enough to have a long-term impact on critical-thinking skills.

Create and evaluate interventions that teach other higher-order thinking skills and focus on instructional strategies that aim to foster the near and far transfer of those skills. If the transfer of skills is not significant, determine what can be done to help ensure the transfer of skills. This is important because, ultimately, graduates need to be able to apply logical thinking and other higher-order thinking skills in both the workplace and their daily activities.

Compare learners working through the materials cooperatively in dyads and triads to those learning individually to determine if cooperative learning should be recommended as a part of future interventions.

Determine if there are differences in using stand-alone materials that teach logical thinking or other higher-order thinking skills in schools where rote memorization is the norm through to schools where thinking skills are regularly emphasized. For example, differences could be found in the performance gains and attitudes of learners as well as attitudes of teachers. If there are differences, determine what, if anything, needs to be done to create effective materials for individuals who have different histories with respect to higher-order thinking skills.

Determine what needs to be done to change educational systems, ranging from government standards or requirements through to the classroom teacher, so that higher-order thinking development becomes a high enough priority so that typical graduates leave the school system with the higher-order thinking skills needed in both the workplace and life itself.

5.7 Conclusion

This study's objectives were to qualitatively assess whether the educational-software and paper-based materials had the attributes to teach effectively, and quantitatively assess the efficacy of the materials. Given the limitations of this study,

the qualitative findings showed that it was deduced that the reviewers thought that both the educational-software and paper-based materials had the attributes to effectively teach logical-thinking skills and the quantitative findings showed that both the educational software and paper-based interventions led to significant gains in logical-thinking skills, although a few of the specific logical-thinking tests did not show significant gains.

This research helps to fill the gap in research regarding teaching logical-thinking skills, particularly with standalone educational software and paper-based materials that aim to teach grade six and seven students logical-thinking skills. However, more research and interventions are needed to fully solve the problem of students leaving the school system without the level of logical-thinking skills needed to reach one's full potential in both the workplace and life in general.

References

- Abdellatif, H. R. (2008). *Analogical reasoning in elementary school children: The role of age and relational knowledge* (Doctoral dissertation, University of Nevada, 2007).
- Abrami, P., et al. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research* 78(4), 1102-1134.
- Al-Hadlaq, A. (1994). *Quality software: An analysis using Gagné's nine events of instruction* (Doctoral dissertation, Ohio University, 1994).
- Allison, A. K. (1993). *Critical thinking/problem-solving skills for the at-risk student* (Doctoral dissertation, Northern Arizona University, 1993).
- Allrich, R. P. (2002). *The investigation of learning within a nursing preceptorship clinical experience: A naturalistic inquiry* (Doctoral dissertation, University of Texas, 2002).
- Almatrodi, D. (2007). *Effective critical thinking teaching strategies as perceived by affiliated program evaluation faculty* (Doctoral dissertation, Western Michigan University, 2007).
- Andrusyszyn, M. (1996). *Facilitating reflection in computer mediated learning environments* (Doctoral dissertation, University of Toronto, 1996).
- Arslan, S., & Akin, A. (2014). Metacognition: As a predictor of one's academic locus of control. *Educational Sciences: Theory & Practice* 14(1), 33-39.
- Asamani, J. B. (1998). *An experimental study of the relationship between cooperative learning and critical thinking* (Doctoral dissertation, Tennessee State University, 1995).
- Astleitner, H. (2002). Teaching critical thinking. *Journal of Instructional Psychology* 29(2), 53-77.
- Bachann, M. (1995). *Mental process model approach to detect judgment bias and knowledge based approach to critic human judgement* (Doctoral dissertation, George Washington University, 1995).
- Baker, L., & Wigfield, A. (2011). *Dimensions of children's motivation for reading and their relations to reading activity and reading achievement*. Retrieved October 22, 2012, from <https://www.msu.edu/~dwong/CEP991/CEP991Resources/Baker%26Wigfield-MotivRdng.pdf>.
- Barns, C., & Monroe, R. (2011). *Reading motivation: Strategies to motivate struggling readers K-8*. Retrieved October 22, 2012, from <http://www.appstate.edu/~koppenhaverd/rcoe/s11/5040/papers/candace&rachel.pdf>.

- Barak, M. (2009, November). Idea focusing versus idea generating: A course for teachers on inventive problem solving. *Innovations in Education and Teaching International* 46(4), 345-356.
- Bass, G. M., & Perkins, H. W. (1984). Teaching critical thinking skills with CAI. *Electronic Learning* 14(2), 32, 34, 96.
- Baumer, E. (2009). *Computational metaphor identification to foster critical thinking and creativity*. (Doctoral dissertation, University of California, 2009).
- Baylor, A. L., & Kozbe, B. (1998). A personal intelligent mentor for promoting metacognition in solving logic word problems. *Paper Presented at the Fourth World Congress on Expert Systems, Mexico City, Mexico*.
- Belmont, A. S. (1991). *Critical thinking – problem solving: A unified framework for teaching a process approach* (Doctoral dissertation, University of Massachusetts, 1991).
- Bessick, S. (2008). *Improved critical thinking skills as a result of direct instruction and their relationship to academic achievement* (Doctoral dissertation, Indiana University of Pennsylvania, 2008).
- Bloom, B., Engelhart, M., Hill, W., Furst, E., & Krathwohl, D. (1956). *Taxonomy of educational objectives, Handbook 1: The cognitive domain*. New York, NY: David McKay Inc.
- Bowers, B. (1991, Spring). Teacher involvement in curriculum development. *Research Roundup* 7(3), 1-5.
- Bowman, L. E. (2000). *Philosophy professors' conception, teaching, and assessment of critical thinking* (Doctoral dissertation, Oklahoma State University, 2000).
- Bradberry-Guest, K. (2011). *Effects of computer-based intervention on higher order thinking skills and implications for response to intervention (RTI)* (Doctoral dissertation, Walden University, 2011).
- Brown, V. E. (2000). *Analogical reasoning: Constraint preference among third grade students(a concept revisited)* (Doctoral dissertation, University of Florida, 2000).
- Bullen, M. (1997). *A case study of participation and critical thinking in a university-level course delivered by computer conferencing* (Doctoral dissertation, University of British Columbia, 1997).
- Burkhart, L. M. (2006). *Thinking critically about critical thinking: Developing thinking skills among high school students* (Doctoral dissertation, Claremont Graduate University, 2006).
- Byland, H. (2005). *Fostering critical thinking skills through peer response and self-assessment* (Master's degree thesis, University of Alabama, 2005).
- Campbell, D., & Stanley, J. (1966). *Experimental and quasi-experimental designs for research*. Chicago, IL: Rand McNally Publishing Company.

- Campbell, J. P. (2000). *A comparison of computerized and traditional instruction in the area of elementary reading* (Doctoral dissertation, University of Alabama, 2000).
- Carwie, L. (2010). *The Effect of Computer-Supported Argument Mapping on the Critical Thinking Skills of Undergraduate Nursing Students* (Doctoral dissertation, University of South Alabama, 2009).
- Chapman, D. M. (1985). *Teaching and evaluating clinical reasoning through computer-based patient management simulations* (Doctoral dissertation, Brigham Young University, 1985).
- Christian, R. D. (1995). *A design for teaching preservice secondary social studies teachers methods for teaching critical thinking skills* (Doctoral dissertation, Illinois State University, 1995).
- Clark, D. (2005). *Critical Thinking*. Retrieved September 8, 2014, from <http://www.nwlink.com/~donclark/creativity/criticalthinking.html>.
- Clark, R. E. (1983). Reconsidering research on learning from media. *Review of Educational Research*, 53(4), 445-459.
- Coffee, H. (2009). *Zone of proximal development*. Retrieved November 7, 2012, from <http://www.learnnc.org/lp/pages/5075>.
- The effectiveness of computer-delivered correction procedures on low-performing secondary students' reasoning skills (feedback, cognitive, logic)* (Doctoral dissertation, University of Oregon, 1984).
- Commeyras, M. (1991). *Dialogical-thinking reading lessons: Promoting critical thinking among "learning disabled" students* (Doctoral dissertation, University of Illinois, 1991).
- Cott, A. M. (1991). *On the efficacy of programmed instruction on training creative problem solving strategies* (Doctoral dissertation, Hofstra University, 1991).
- Cotton, K. (1991). *Close-Up #11: Teaching Thinking Skills*. Retrieved January 3, 2007, from <http://www.nwrel.org/scpd/sirs/6/cu11.html>.
- Cousins, J. B., & Ross, J. A. (1993). Improving higher order thinking skills by teaching "with" the computer: A comparative study. *Journal of Research on Computing in Education*, 26(1), 94-115.
- Craig, J. (2007). *E²: Efficient and effective e-learning* (Doctoral dissertation, Capella University, 2007).
- Crone-Todd, D. E. (2002). *Increasing the levels at which undergraduate students answer questions in a computer-aided personalized system of instruction course* (Doctoral dissertation, University of Manitoba, 2002).
- Cropley, A. (2006). In praise of convergent thinking. *Creativity Research Journal* 18(3), 391-404.

- D'Antoni, A. V. (2009). *Relationship between the mind map learning strategy and critical thinking in medical students* (Doctoral dissertation, Seton Hall University, 2009).
- Davis-Seaver, J. (1994). *Critical thinking in young children* (Doctoral dissertation, University of North Carolina, 1994).
- Dawson, C. (2006). *A practical guide to research methods: A user-friendly manual for mastering research techniques and projects* (2nd ed.). Oxford, United Kingdom: How To Books.
- Deines, H. G. (1997). *Modeling thinking in practice: Content analysis of social work field practicum texts* (Doctoral dissertation, Spalding University, 1997).
- Dick, W., & Carey, L. (1990). *The systematic design of instruction* (3rd ed.). Glenville, IL: Harper Collins Publishers.
- Diep, K. C. (2011). *A conceptual framework for best practices in information literacy instruction based on stakeholders' perceptions: A case study of four vietnamese academic libraries* (Doctoral dissertation, University of Hawaii, 2011).
- Dhingra, R., & Sharma, N. (2012, March). Assessment of divergent thinking ability of school children (6 – 9 years). *International Journal of Academic Research* 4(2), 155-162.
- Donahoe, S. D. (2001). *Instruction of critical thinking skills in a state standards-based testing program: A case study of the perceptions of middle school social studies teachers on the impact of the Virginia standards of learning and assessments on the instruction of critical thinking skills* (Doctoral dissertation, Virginia Commonwealth University, 2001).
- Duffield, J. (1989). *Problem-solving software: What does it teach?* (Doctoral dissertation, Florida State University, 1989).
- Dunn, R., & Bruno, A. (1985, September). What does the research on learning styles have to do with Mario? *The Clearing House*, 59(1), 9-12.
- Dunning, T. (2008). *The application of design for six sigma to the development of web-based training for clinical laboratory personnel* (Master's degree thesis, California State University, 2008).
- El-Sanhurry, N. (1990). *Effects of freedom to control a science learning sequence of computer-based instruction on achievement and attitudes of junior high school formal and non-formal reasoners* (Doctoral dissertation, University of Minnesota, 1990).
- Elder, L., & Paul, R. (2002). Critical thinking: Distinguishing between inferences and assumptions. *Journal of Developmental Education* 25(3), 34-35.
- Ellingwood, M. (1997). *The effects of Logo instruction on the higher-order thinking skills and mathematical achievement on male and female first grade students* (Doctoral dissertation, University of South Alabama, 1997).

- Enniss, I. (2006). *A qualitative analysis of the kinds of higher-order thinking processes present in the reflective journals of graduate students of reading theory* (Doctoral dissertation, Wayne State University, 2006).
- Etsey, K. F. (2004). *The effects of comprehension strategy instruction on Ghanaian English language learners' comprehension processes and text understanding* (Doctoral dissertation, University of Iowa, 2004).
- Facione, P. A., & Facione, N. C. (1994). *The California critical thinking skills test: Test manual*. Millbrae, CA: The California Academic Press.
- Facione, P. A., & Facione, N. C. (2009). *How to use the Holistic Critical Thinking Scoring Rubric*. Retrieved May 7, 2011, from http://www.insightassessment.com/pdf_files/Rubric%20HCTSR.pdf.
- Fanetti, T. M. (2011). *The effect of problem-solving video games on the science reasoning skills of college students* (Doctoral dissertation, University of Missouri, 2011).
- Fenrich, P. (2014). *Practical principles of instructional design, media selection, and interface design with a focus on computer-based training / educational software*. Santa Rosa, CA: Informing Science Press.
- Fenrich, P. (2002). An instructional model for teaching troubleshooting skills. *Proceedings of the Informing Science and IT Education Conference, June 19-21, Cork, Ireland*.
- Floyd, D. M. (1992). *Coming to know: Prospective elementary teachers' thinking and the case study approach* (Doctoral dissertation, Florida State University, 1992).
- Frear, V. (1997). *The effects of students' involvement with the content of science-based interactive multimedia on: achievement, attitudes, and higher level thinking skills* (Doctoral dissertation, University of Akron, 1997).
- Gagné, R., Briggs, L., & Wager, W. (1988). *Principles of instructional design* (3rd ed.). New York, NY: Holt, Rinehart and Winston.
- Galinski, M. (1988). *An investigation of the relationship of microcomputer problem-solving software and critical thinking abilities of junior-high students* (Doctoral dissertation, Northeastern University, 1988).
- Gallavan, N. P., & Kottler, E. (2012). Advancing social studies learning for the 21st century with divergent thinking. *The Social Studies 103*, 165-170.
- Gammill, E. B. (2000). *Implementing curriculum reform in associate degree nursing programs: Preparing nurses to be critical thinkers* (Doctoral dissertation, University of California, 2000).
- Gilhooly, K. J., Georgiou, G. J., Garrison, J., Reston, J. D., & Sirota, M. (2012). Don't wait to incubate: Immediate versus delayed incubation in divergent thinking. *Memory & Cognition 40*, 966-975.

- Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. *Proceedings of the Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education, October 8-10, Columbus, Ohio.*
- Goh, W. (2008). *Dialogic argumentation as a path to enhancing individual argumentive reasoning in academically disadvantaged 8th-graders* (Doctoral dissertation, Columbia University, 2008).
- Goldstein, D., Hahn, C., Hasher, L., Wiprzycka, U., & Zelazo, P. (2006). *Does it compute? Time of day, intellectual performance, and behavioral problems in Morning versus Evening type adolescents: Is there a synchrony effect?* Retrieved April 15, 2012, from <http://www.psych.utoronto.ca/users/dgoldst/Goldstein%20et%20al%20in%20press.pdf>
- Grossen, B. (1988). *A study of the effect of response form in computer-assisted instruction of class reasoning skills* (Doctoral dissertation, University of Oregon, 1988).
- Gruberman, R. S. (2005). *Teaching conceptualizations of higher-order thinking: A case study* (Doctoral dissertation, Boston College, 2005).
- Hall, T. (2005). *Critical thinking, self-direction and online learning: A practical inquiry perspective in higher education* (Doctoral dissertation, University of South Dakota, 2005).
- Halsted, S. E. (1998). *Facilitating creative and critical thinking in middle school science* (Master's degree thesis, Pacific Lutheran University, 1998).
- Hart, S. M. (2008). *The design decisions of teachers during technology integration* (Doctoral dissertation, Wayne State University, 2008).
- Hendricks, C. (1998). *Effects of instruction in sequencing for first graders* (Doctoral dissertation, George Mason University, 1998).
- Heo, J. (2012). *The effect of using three types of instructional media on comprehension and motivation of Korean college students in an online course* (Doctoral dissertation, University of Nevada, 2012).
- Huff, M. T. (1998). *A comparison of critical thinking in an interactive television social work course* (Doctoral dissertation, University of South Carolina, 1998).
- Huff-Benkoski, K. A. (1998). *The effects of word analogy instruction on developing readers* (Doctoral dissertation, Lehigh University, 1998).
- Hughes, B. E. (2009). *An exploration of self-reflection and critical-thinking exhibited in visual-arts students' portfolios at the secondary level* (Doctoral dissertation, University of San Francisco, 2009).
- Hugo, J. L. (1989). *A qualitative evaluation study of a thinking skills program for teachers and students* (Doctoral dissertation, University of Denver, 1989).

- Hunter, K. A. (2010). *Fifth grade students' response to a multicultural study of the middle ages: An exploration of the use of multiple genres and multiple modalities* (Doctoral dissertation, University of Pennsylvania, 2010).
- Hurst, R. W., & Milkent, M. M. (1994). Facilitating successful predictive reasoning in biology through application of skill theory. *Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, March 19-26, Anaheim, California.*
- Hurte, V. J. (2004). *A comparison of the scaffolding approach and the cognitive enrichment advantage approach in enhancing critical thinking skills in first-year university freshmen* (Doctoral dissertation, University of Tennessee, 2004).
- Irwin, R. R. (1995). *Intellectual development and computer-assisted instruction: The improvement of dialectical thinking and argumentative writing* (Doctoral dissertation, York University, 1995).
- Jeremiah, K. (2012). *Understanding approaches to teaching critical thinking in high school classrooms* (Doctoral dissertation, Walden University, 2012).
- Jensen, J. L. (2008). *Effects of collaboration and inquiry on reasoning and achievement in biology* (Doctoral dissertation, Arizona State University, 2008).
- Johnson, D. M. (1997). *The effects of a training program on the analogical reasoning abilities of elementary school-aged children* (Doctoral dissertation, Howard University, 1996).
- Joshua, J. M. (2014). The influence of students' experience in the past academic success on convergent thinking. *IFE Psychologia* 22(1), 159-169.
- Judy, J. E. (1987). *Effects of two instructional approaches and peer tutoring on gifted and nongifted sixth graders' analogy performance* (Doctoral dissertation, Texas A&M University, 1987).
- Kaplan, I. S. (1997). *An assessment of the infusion of critical thinking skills into content instruction* (Doctoral dissertation, University of Massachusetts Amherst, 1997).
- Katzlberger, T. (2006). *Learning by teaching agents* (Doctoral dissertation, Vanderbilt University, 2005).
- King, S. L. (2008). *The effect of analogy instruction on first graders' analogical reasoning and reading comprehension* (Doctoral dissertation, Tennessee State University, 2008).
- Kingston, L. S. (2011). *Virtual world, real education: A descriptive study of instructional design in Second Life* (Doctoral dissertation, Capella University, 2011).
- Kleibeuker, S. W., De Dreu, C., & Crone, E. A. (2013). The development of creative cognition across adolescence: Distinct trajectories for insight and divergent thinking. *Developmental Science* 16(1), 2-12.

- Kreyche, D. (2002). *A field test of CAI software - Powers of Persuasion: World War II Propaganda* (Master's degree thesis, California State University, 2002).
- Lafferty, I. (1996). *Analysis of the computerized structure of intellect teaching thinking intervention* (Doctoral dissertation, Harvard University, 1996).
- Lamb, A. (2001). *Critical and Creative Thinking – Bloom's Taxonomy*. Retrieved March 28, 2014, from <http://eduscapes.com/tap/topic69.htm>.
- Lane, M. L. (2003). *The effects of staff development on student achievement* (Doctoral dissertation, University of Denver, 2003).
- Larson, M. E. (2010). *Transfer of learning: The effects of different instruction methods on software application learning* (Doctoral dissertation, Capella University, 2010).
- Larson, A., Britt, A., & Kurby, C. (2009). Improving students' evaluation of informal arguments. *The Journal of Experimental Education* 77(4), 339-366.
- Lee, J. S. (2010). *Outcomes and implications of designing and implementing a project-based learning geometry unit* (Doctoral dissertation, Indiana University, 2010).
- Lee, Y. (2008). *The effects of different levels of vicarious interactions on critical thinking* (Doctoral dissertation, Purdue University, 2008).
- Legant, L (2010). *A case study examining critical thinking in an elementary service-learning project* (Doctoral dissertation, Walden University, 2010).
- Leiker, V. (1993). *The relationship between an integrated learning system, reading and mathematics achievement, higher-order thinking skills and certain demographic variables: A study conducted in two school districts* (Doctoral dissertation, Baylor University, 1993).
- Lewis, R. B. (1998). *Developing critical thinking through an interdisciplinary approach with social studies simulations and technology in fourth grade classrooms* (Doctoral dissertation, Tennessee State University, 1998).
- Lieberman, M. (2007). *An electronic-based learning tool for strategy and strategic thinking* (Doctoral dissertation, Pepperdine University, 2007).
- Liu, C. (2006). *Connecting the dots between critical thinking skills and dispositions for middle school students* (Doctoral dissertation, Wayne State University, 2006).
- Loiacono, C. M. (2000). *Promoting freshman college student development using cognitive developmental theory presented in a deliberate psychological education-based freshman orientation program* (Doctoral dissertation, College of William & Mary, 2000).
- Mackenburg-Mohn, M. D. (2006). *Enhancing critical thinking in baccalaureate nursing programs through the use of computer assisted learning activities* (Doctoral dissertation, Capella University, 2006).

- Mains, M. G. (1997). *The effects of learning a programming language on logical thinking skills* (Master's degree thesis, University of Nevada, 1997).
- Martineau-Gilliam, V. (2007). *Effective writing-across-the-curriculum activities and support services for non-traditional adult students* (Doctoral dissertation, University of La Verne, 2007).
- Maryannakis, A. (2009). *Effectiveness of objectivist online instruction on graduate learners' knowledge and competence* (Doctoral dissertation, Capella University, 2009).
- Masteron, J., & Perrey, C. (1999). Training analogical thinking skills in children with language disorders. *American Journal of Speech-Language Pathology* 8(1), 53-61.
- Mayes, R. L. (1995). The application of a computer algebra system as a tool in college algebra. *School Science and Mathematics* 95(2), 61-68.
- Mayrath, M. C. (2009). *Examining factors that affect performance in complex simulation environments* (Doctoral dissertation, University of Texas, 2009).
- McCormick, G. J. (1988). *The effects of using print media in teaching critical thinking skills to adult students* (Doctoral dissertation, Western Michigan University, 1988).
- McDonald, D. M. (2003). *Teaching for scientific understanding: A study of the effects of two methods* (Master's degree thesis, University of Manitoba, 2003).
- McKenzie, S. (1999). *Achievement and affective domains of Algebra I students in traditional or self-paced computer programs* (Doctoral dissertation, University of Southern Mississippi, 1999).
- McMillen, R. (2008). *Computer-assisted instruction and tennis doubles strategy* (Master's degree thesis, California State University, 2007).
- McNamee, M. M. (2011). *The Impact of Brain-Based Instruction on Reading Achievement in a Second-Grade Classroom* (Doctoral dissertation, Walden University, 2011).
- Meins, K. (1991). *A descriptive analysis of the teaching of critical thinking skills in teacher education programs in universities and colleges in the state of Arkansas* (Doctoral dissertation, University of Arkansas, 1991).
- Meyer, K. E. (2010). *The rivalry between simulation and problem-based learning: A study of learning transfer in physician assistant students* (Doctoral dissertation, Capella University, 2010).
- Miller, M. G. (2003). *Holistic design for critical thinking instruction: Case studies of instructional practices* (Doctoral dissertation, Concordia University, 2003).
- Mintz, K. (2000). *A comparison of computerized and traditional instruction in elementary mathematics* (Doctoral dissertation, University of Alabama, 2000).

- Mitchell, M., & Jolley, J. (1988). *Research design explained*. New York, NY: Holt Rinehard and Winston, Inc.
- Moran, K. M. (1989). *Proportional metaphor comprehension and verbal analogical reasoning in school age children* (Master's degree thesis, University of Alberta, 1989).
- Morey, D. (2008). *Effectiveness of web-based animated pedagogical agents: Facilitating critical thinking of nursing students* (Doctoral dissertation, Capella University, 2008).
- Oloruntegbe, K.O., et al. (2010). Teachers' involvement, commitment and innovativeness in curriculum development and implementation. *Educational Research* 1(12), 706-712.
- Orabuchi, I. (1992). *Effects of using interactive CAI on primary students' higher-order thinking skills: Inferences, generalizations, and math problem-solving* (Doctoral dissertation, Texas Woman's University, 1992).
- Parsons, A. M. (2008). *A Delphi study of best practices of online instructional design practices in Malaysia* (Doctoral dissertation, Capella University, 2008).
- Paul, R., & Elder, L. (2006). *The miniature guide to critical thinking concepts and tool* (4th ed.). Dillon Beach, CA: Foundation for Critical Thinking.
- Paul, R., & Elder, L. (1999a). Critical thinking: Teaching students to seek the logic of things, part II. *Journal of Developmental Education* 23(2), 34-36.
- Paul, R., & Elder, L. (1999b). Critical thinking: Teaching students to seek the logic of things. *Journal of Developmental Education* 23(1), 34-35.
- Peterson, B. L. (2012). *The effect of computer interactive simulation on situational decision-making and competency development of experienced staff nurses* (Doctoral dissertation, University of Kansas, 2012).
- Petris, E. A. (2009). *Developing reading comprehension skills in third grade students through the modeling of higher order critical thinking questions* (Master's degree thesis, Caldwell College, 2008).
- Phillips, J. A. (2005). HMEF 5014 *Education research methodology*. Kuala Lumpur, Malaysia: Open University Malaysia.
- Phillips, S. (1992). *Achievement of generic baccalaureate student nurses using computer-assisted instruction simulations during a nursing review course* (Doctoral dissertation, Florida International University, 1992).
- Pogrow, S. (2005). HOTS revisited: A thinking development approach to reducing the learning gap after grade 3. *Phi Delta Kappan* 87(1), 64-75.
- Pogrow, S. (1990). A Socratic approach to using computers with at-risk students. *Educational Leadership* 47(5), 61-66.

- Pond, E. F. (1987). *The development and validation of a computer assisted instructional program in parent-child nursing designed to enhance the critical thinking skills of baccalaureate nursing students* (Doctoral dissertation, University of Georgia, 1987).
- Powell-Laney, S. K. (2010). *The use of human patient simulators to enhance the clinical decision making of nursing students* (Doctoral dissertation, Walden University, 2010).
- Raidl, M. A. (1993). *Effectiveness of computer assisted instruction (CAI) in dietetic education* (Doctoral dissertation, Purdue University, 1993).
- Reddy, S. (2008). *Developing, implementing and evaluating computer-based instruction* (Doctoral dissertation, Indiana State University, 2008).
- Reed, J. H. (1999). *Effect of a model for critical thinking on student achievement in primary source document analysis and interpretation, argumentative reasoning, critical-thinking dispositions, and history content in a community college history course* (Doctoral dissertation, University of South Florida, 1998).
- Reid, J. R. (2010). *A quantitative assessment of an application of Halpern's teaching for critical thinking in a business class* (Doctoral dissertation, Northern Illinois University, 2010).
- Rendall, L. T. (2001). *The effectiveness of a computer-based instruction program: A comparative study* (Doctoral dissertation, Temple University, 2001).
- Repman, J. L. (1989). *Cognitive and affective outcomes of varying levels of structured collaboration in a computer-based learning environment* (Doctoral dissertation, Louisiana State University, 1989).
- Rigmaiden, P. Q. (2011). *The effects of study guides that feature taxonomically structured question sets in sixth grade social studies* (Doctoral dissertation, Capella University, 2011).
- Rivière, F. (1990). *Developing problem solving abilities with artificial intelligence* (Master degree thesis, University of Windsor, 1993).
- Robertson, C. L. (2005). *Development and transfer of higher order thinking skills in pilots* (Doctoral dissertation, Capella University, 2005).
- Rocks, J. E. (2004). *Do transfer of learning and student involvement variables affect the student athletic trainer's outcome on the written simulation scores of the National Certification Examination?* (Doctoral dissertation, University of Toledo, 2004).
- Rodriguez, E. L. (2009). *The use of blended learning to facilitate critical thinking in entry level occupational therapy students* (Doctoral dissertation, Capella University, 2009).
- Roop, K. M. (2002). *Effect of concept mapping as a learning strategy on certificate practical nursing students' academic achievement and critical thinking development* (Doctoral dissertation, Wilmington College, 2002).

- Rosenshine, B. (2012). *Principles of instructions: Research-based strategies that all teachers should know*. Retrieved October 22, 2012, from <http://www.aft.org/pdfs/americaneducator/spring2012/Rosenshine.pdf>.
- Rothman, A. H. (2000). *The impact of computer-based versus "traditional" textbook science instruction on selected learning outcomes* (Doctoral dissertation, Temple University, 2000).
- Rukavina, P. (2003). *The effect of scaffolding movement challenges on students' task-related thoughts and performance* (Doctoral dissertation, Louisiana State University, 2003).
- Ruzhitskaya, L. (2012). *The effects of computer-supported inquiry-based learning methods and peer interaction on learning stellar parallax* (Doctoral dissertation, University of Missouri-Columbia, 2011).
- Scher, D. M. (1999). *Relations between stance and critical thinking in seventh graders' responses to narrative and expository texts* (Doctoral dissertation, University of Maryland, 1999).
- Schmidt, D. (1991). *An investigation of the effect of gender, cognitive level, and attitude of seventh-grade science students on an identification of key variables task using an expert system* (Doctoral dissertation, Florida Atlantic University, 1991).
- Schüblová, M. (2008). *The effect of using computer simulations as self-directed learning on critical thinking levels in entry-level athletic training students* (Doctoral dissertation, Ohio University, 2008).
- Semper Scott, L. D. (2005). *The cognitive emphasis of instruction as demonstrated by assessment practices* (Doctoral dissertation, American University, 2005).
- Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information* 22, 63-75.
- Shiah, R. (1994). *The effects of computer-assisted instruction on the mathematical problem solving of students with learning disabilities* (Doctoral dissertation, Purdue University, 1994).
- Shin, S. (2002). *The effects of a metacognitive art criticism teaching strategy that incorporates computer technology on critical thinking skill and art critiquing ability* (Doctoral dissertation, Florida State University, 2002).
- Shinnick, M. A. (2010). *The impact of human patient simulation on nursing clinical knowledge* (Doctoral dissertation, University of California, 2010).
- Singh, O. B. (2010). *Development and validation of a web-based module to teach metacognitive learning strategies to students in higher education* (Doctoral dissertation, University of South Florida, 2009).
- Slattery, A. P. (1989). *A study of the effects of logical language training on reading comprehension* (Doctoral dissertation, Boston College, 1989).

- Soeherman, S. (2010). *The relationships of critical thinking skills, critical thinking dispositions, and college experiences of theological students in Indonesia* (Doctoral dissertation, Biola University, 2010).
- Solomon, G. (2008). *Pilot study: Application of constructive theory to educational software architecture* (Doctoral dissertation, American University, 2008).
- Sondel, H. B. (2009). *The effects of curricular programs on aspects of critical thinking as applied to writing* (Doctoral dissertation, University of Virginia, 2009).
- Stambaugh, T. L. (2007). *Effects of the Jacob's Ladder Reading Comprehension Program on reading comprehension and critical thinking skills of third, fourth, and fifth grade students in rural, Title I schools* (Doctoral dissertation, The College of William and Mary, 2007).
- Stratton, E. W. (2003). *Effects of web-based instruction in high school chemistry* (Master's degree thesis, University of North Texas, 2003).
- Subramanian, L. (2005). *An investigation of high school geometry students' proving and logical thinking abilities and the impact of dynamic geometry software on student performance* (Doctoral dissertation, University of Central Florida, 2005).
- Svenningsen, L. (2009). *An examination of the effect of CAPSI as a learning system in developing knowledge and critical thinking in two blended learning courses* (Doctoral dissertation, University of Manitoba, 2009).
- Swan, K. (1990). *Logo programming and the teaching and learning of problem solving* (Doctoral dissertation, Columbia University, 1989).
- Sykes, M. S. (1990). *The effects of instructional interventions for at-risk secondary students* (Doctoral dissertation, Texas Woman's University, 1990).
- Tarkington, S. A. (1988). *Improving critical thinking skills using Paideia seminars in a seventh grade literature curriculum* (Doctoral dissertation, University of San Diego, 1988).
- Taylor, C. S. (1997). *Differences in formal reasoning in terms of frontal lobe functioning* (Doctoral dissertation, Texas Tech University, 1997).
- Terry, D. R. (2007). *Using the case study teaching method to promote college students' critical thinking skills* (Doctoral dissertation, State University of New York, 2007).
- A. (1999a). *The effects of computer-based instruction on the academic achievement of at-risk students*. (ERIC Document Reproduction Service No. ED457855).
- Thomas, P. E. (1999b). *Critical thinking instruction in selected greater Los Angeles area high schools* (Doctoral dissertation, Azusa Pacific University, 1999).
- Thomson, S. (2009). *Effects of Primary Education Thinking Skills™ on achievement: Mixed-method evaluative study* (Doctoral dissertation, Aurora University, 2009).

- Tilson, E. R. (1986). *The effect of computer enhanced skill training in critical thinking and cognitive monitoring on learning and development of critical thinking in an undergraduate family nursing course* (Doctoral dissertation, University of Georgia, 1986).
- Jay, E., & Perkins, D. N. (1992). *Teaching thinking dispositions: From transmission to enculturation*. Retrieved January 5, 2007, from <http://learnweb.harvard.edu/ALPS/thinking/docs/article2.html>.
- Titterington, L. C. (2007). *Case studies in pathophysiology: The development and evaluation of an interactive online learning environment to develop higher order thinking and argumentation* (Doctoral dissertation, Ohio State University, 2007).
- Toth, M. H. (1996). *An experimental approach in evaluating instructional strategies to teach critical thinking to freshman nursing students* (Doctoral dissertation, Widener University, 1996).
- Valanides, N. (1996). Formal reasoning and science teaching. *Bowling Green* 96(2), 99-107.
- von Glasersfeld, E. (2001). *Radical constructivism and teaching*. Retrieved May 7, 2011, from <http://www.univie.ac.at/constructivism/EvG/papers/244.2.pdf>
- vonStein, J. H. (1982). *An evaluation of the microcomputer as a facilitator of indirect learning for the kindergarten child* (Doctoral dissertation, Florida Atlantic University, 1982).
- Vowels, C. L. (2008). *Training an implicit reasoning strategy: Engaging specific reasoning processes to enhance knowledge acquisition* (Doctoral dissertation, Kansas State University, 2008).
- Walker, S. E. (2001). *The effects of two instructional methodologies on the critical thinking skills of undergraduate athletic training students* (Doctoral dissertation, University of Southern Mississippi, 2001).
- Webb, S. K. (1997). *A comparative assessment of two distinct teaching methods in economics education of twelfth grade students at Hoover High School as measured by students' scores on economic literacy and economic attitudes* (Doctoral dissertation, University of Alabama, 1997).
- Wellman, L. A. (1997). *The use of multiple representations, higher order thinking skills, interactivity, and motivation when designing a CD-ROM to teach self similarity* (Doctoral dissertation, University of California, 1997).
- Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Retrieved April 24, 2007, from <ftp://ftp.ets.org/pub/res/technolog.pdf>
- Wilber, P. (2000). *Faculty interests—faculty needs: Creating meaningful critical thinking training* (Doctoral dissertation, University of North Dakota, 2000).

- Wilson, A. F. (1986). *The effects of two levels of professional development training in analogical reasoning on fourth-grade students' performance of analogy tasks* (Doctoral dissertation, Texas A & M University, 1986).
- Wilson-Robbins, C. L. (2006). *Assessing critical thinking in asynchronous online learning: A case study of two community college online courses* (Doctoral dissertation, Capella University, 2006).
- Wolfe, F. E. (1999). *Levels of Piagetian development among adult mathematics students* (Doctoral dissertation, University of Minnesota, 1999).
- Wruck, L. M. (2010). *Computer-mediated communication: Instructional design strategies that support the attainment of Bloom's higher order cognitive skills in asynchronous discussion questions* (Doctoral dissertation, Capella University, 2010).
- Wu, X. (2009). *Improving children's engagement and learning through free-flowing discussions: Impact of collaborative reasoning discussion* (Doctoral dissertation, University of Illinois, 2009).
- Wulun, J. (2007). Understanding complexity, challenging traditional ways of thinking. *Systems Research and Behavioral Science* 24, 393-402.
- Yin, R. K. (2003). *Case study research: Design and methods*. Thousand Oaks, CA: Sage Publications.
- Young, J. H. (1988, Winter). Teacher participation in curriculum development: What status does it have? *Journal of Curriculum and Supervision* 3(2), 109-121.
- Young, L. E. & Maxwell, B. (2007). From rote to active learning: Constructivism in the context of teaching theories. In Young, L. E. & B. Paterson (Eds.) *Teaching nursing: Developing a student-centered learning environment*. pp 1-25. Philadelphia, PA: Lippincott, Williams, and Wilkins.
- Yuill, N. (1991). *The effects of computerized problem-solving simulations on critical thinking skills of baccalaureate nursing students* (Doctoral dissertation, Texas Woman's University, 1991).

APPROVAL LETTERS

Letter for Seaforth Elementary School

Dear Mr. Chong:

I would like to work with you to have your grade six and seven students in Seaforth Elementary School participate in a research study. The research study is entitled, "A Comparison of the Effectiveness of Stand-Alone Educational Software to Paper-based Materials Where Both Are Designed to Teach Generic Logical Thinking Skills to Grade Six and Seven Students". As well, the study will evaluate whether each package teaches effectively. This research is part of my PhD requirements of the Open University Malaysia program. This study also fits into my current position, as an Instructional Development Consultant at the British Columbia Institute of Technology, where one of my duties is to conduct educational research.

Although it will not be a part of the study, the materials can equally be used for grade five students if you decide that you would like have those students work through the educational software version of the materials. The paper-based materials could be used but the cost of the paper will be excessive.

The materials are designed to enhance logical thinking skills, which are essential for individuals to function fully in society. The reason for creating these supplemental materials is that an individual's logical thinking skills can often be taught to a higher level than is currently achieved. In some developing countries, logical thinking is not taught at all. Ideally, the educational software will later be used as a resource in Canadian classrooms and hopefully throughout the world.

For the grade six and seven students, the limitation is that about one-third of the students need to be using a computer at the same time while another one-third will be doing the paper-based version. The final one-third will be a control group that has no intervention. The control group can work through each lesson after the data for each lesson is collected. Note that I will need access to a computer lab and/or cart of computers. The software will run on most any PC computer.

There are five lessons. It is estimated that each lesson will take about an hour to complete. A better estimate of the time needed per lesson will be given after the beta-test is completed. The time frame for completing the five lessons is flexible. One possibility is that one lesson could be done each week.

By participating in this research study, students:

- may benefit by developing enhanced skills in their ability to think logically
- will have the satisfaction of helping to contribute to the world's base of knowledge
- are not expected to be at any risk
- may feel some stress at being assessed

- This will be minimized as it will be emphasized that the study will not affect any of their marks.

The research data regarding your students will remain anonymous.

- After the data is collected, your child will be assigned an identification number.
- At this point, your child's name will be permanently erased from the data file.
- Individual data will not be analysed or published. Only group data will be analysed and published.
- After the research is published, the data will be stored in a locked cabinet.
- Seven years after the research is published, all of the data will be destroyed.

Seaforth Elementary School will receive a perpetual site license of the resulting educational software resource.

Feel free to call me at 604-421-2155 (h) if you have any questions or need further information.

I appreciate this opportunity to collaboratively work together.

Sincerely,

Peter Fenrich

Letter for the Parents/Guardians

Dear Parent or Guardian:

A goal in Seaforth's School Plan is to develop the thinking skills of all students. To this end, Seaforth has enlisted the assistance of Peter Fenrich to work with students in Division 1, 2, and 3. Mr. Fenrich has developed some intervention strategies and assessments that we would like to see if improvement in the logical thinking of students can be identified. In addition to possible practical implications of these interventions for Seaforth students, the data collected will be used to support research conducted by Peter Fenrich.

The purpose of this research study, entitled, "A Comparison of the Effectiveness of Stand-Alone Educational Software to Paper-based Materials Where Both Are Designed to Teach Generic Logical Thinking Skills to Grade Six and Seven Students – Research Phase", is to compare an educational software training package to a paper-based training package. As well, the study will evaluate whether each package teaches effectively. This research is part of Mr. Fenrich's PhD requirements at the Open University Malaysia program. This study also fits into his current position, as an Instructional Development Consultant at the British Columbia Institute of Technology, where one of his duties is to conduct educational research.

The instructional materials are designed to enhance logical thinking skills, which are essential for individuals to function fully in society. Ideally, the educational software will later be used as a resource in Canadian classrooms and hopefully in areas throughout the world where logical thinking is not taught at all.

There are five lessons in the instructional materials. Since each lesson will take an average of less than an hour to complete, the time needed to work through the materials can easily be accommodated. As well, about an hour in total will be needed to complete the pre- and post-assessments.

By participating in this study, your child:

- will presumably benefit by developing enhanced skills in his/her ability to think logically
- will have the satisfaction of helping to contribute to the world's base of knowledge
- is not expected to be at any risk
- may feel some stress at being assessed
 - This will be minimized as it will be emphasized that the study is not linked to the curriculum and will not affect any of their marks.

The research data regarding your child will remain anonymous.

- After the data is collected, your child will be assigned an identification number.
- At this point, your child's name will be permanently erased from the data file.
- Individual data will not be analysed or published. Only group data will be analysed and published.
- After the research is published, the data will be stored in a locked cabinet.

- Seven years after the research is published, all of the data will be destroyed.

Participation in this study is totally voluntary. Your child may withdraw from this study at any time, without consequence. If your child does not participate in the study, he/she will be assigned “regular” tasks by the teacher.

If you and/or your child wish, you can receive a free electronic copy of the research results. As well, the Burnaby School District will receive a free copy of the resulting educational software resource.

For further information, please call Peter Fenrich at 604-421-2155 if you have any questions. The faculty advisor, Dr. John Phillips of Open University Malaysia, can be contacted at johnarul@oum.edu.my. If you have any concerns about your child’s rights or treatment as a research subject, you may contact the Research Ethics Review Board at research_ethics@bcit.ca or call Dr. Norman Streat at 604-432-8815.

Sincerely,



Peter Fenrich
Researcher

K. Chong
Principal

Research Study

I consent ____ I do not consent ____

for _____ to participate in the research study entitled, “A Comparison of the Effectiveness of Stand-Alone Educational Software to Paper-based Materials Where Both Are Designed to Teach Generic Logical Thinking Skills to Grade Six and Seven Students”.

Name: _____ Date: _____

Signature: _____

=====

Please keep the following copy for your personal records.

Research Study

I consent ____ I do not consent ____

for _____ to participate in the research study entitled, “A Comparison of the Effectiveness of Stand-Alone Educational Software to Paper-based Materials Where Both Are Designed to Teach Generic Logical Thinking Skills to Grade Six and Seven Students”.

Name: _____ Date: _____

Signature: _____

PRE-TESTS AND POST-TESTS

For the following pre-tests and post-tests:

- “One for all and all for one” is the classification skill.
- “What’s missing?” is the analogical-reasoning skill.
- “What’s next” is the sequencing skill.
- “Fitting in” is the patterning skill.
- “Clues” is the deductive-reasoning skill.

1. One For All and All For One

Before Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

Given: eight four six

Circle the word that has the same thing in common as the given words:

add count even numbers two

Solution

Given: eight four six

Circle the word that has the same thing in common as the given words:

add count even numbers two

Each of the given words is a number. Two is also a number.

Please **wait** until you are told to begin.

Before Activities Assessment Questions

For each, circle the word that has the same thing in common as the given words.

1. Given: chair refrigerator stove
cook cup eat sit taste
2. Given: lake ocean puddle
evaporate pond rain river water
3. Given: bus plane taxi
fuel ticket train travel wheels
4. Given: France Japan Russia
Asia country India London travel
5. Given: convince influence sway
advice compel debate discourage persuade
6. Given: clutch grasp grip
clasp hand purse release worry
7. Given: arrow pencil scissors
break cut eraser spear weapon
8. Given: cold hot tepid
chilly soup temperature thermometer weather
9. Given: cube cylinder sphere
earth geometry pyramid rectangle shape
10. Given: bear fore pair
car dog ear part sun

1. One For All and All For One

After Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

Given: eight four six

Circle the word that has the same thing in common as the given words:

add count even numbers two

Solution

Given: eight four six

Circle the word that has the same thing in common as the given words:

add count even numbers 

Each of the given words is a number. Two is also a number.

Please **wait** until you are told to begin.

After Activities Assessment Questions

For each, circle the word that has the same thing in common as the given words.

1. Given: bathtub soap toilet
bathe change privacy sink wash
2. Given: city town state
geography government location travel village
3. Given: plane train truck
freighter fuel navigate travel wheels
4. Given: China England Russia
Africa country Egypt travel Tokyo
5. Given: hinder inhibit oppose
debate hamper hide revert support
6. Given: mighty robust strong
controlling leader powerful weak winner
7. Given: axe razor scissors
bandage cut knife slice think
8. Given: dark dim light
bright bulb day electricity lamp
9. Given: rectangle square triangle
angle circle cube geometry line
10. Given: fare pore too
cat ear moon part their

Before Activities Assessment Solutions

1. Given: chair refrigerator stove
cook **cup** eat sit taste
2. Given: lake ocean puddle
evaporate **pond** rain river water
3. Given: bus plane taxi
fuel ticket **train** travel wheels
4. Given: France Japan Russia
Asia country **India** London travel
5. Given: convince influence sway
advice compel debate discourage **persuade**
6. Given: clutch grasp grip
clasp hand purse release worry
7. Given: arrow pencil scissors
break cut eraser **spear** weapon
8. Given: cold hot tepid
chilly soup temperature thermometer weather
9. Given: cube cylinder sphere
earth geometry **pyramid** rectangle shape
10. Given: bear fore pair
car dog ear part **sun**

After Activities Assessment Solutions

1. Given: bathtub soap toilet
bathe change privacy **sink** wash
2. Given: city town state
geography government location travel **village**
3. Given: plane train truck
freighter fuel navigate travel wheels
4. Given: China England Russia
Africa country **Egypt** travel Tokyo
5. Given: hinder inhibit oppose
debate **hamper** hide revert support
6. Given: mighty robust strong
controlling leader **powerful** weak winner
7. Given: axe razor scissors
bandage cut **knife** slice think
8. Given: dark dim light
bright bulb day electricity lamp
9. Given: rectangle square triangle
angle **circle** cube geometry line
10. Given: fare pore too
cat ear moon part **their**

2. What's Missing?

Before Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

hot → cold : warm → _____ (Read this as: Hot is to cold as warm is to _____.)

Circle the word that fits best:

cool freezing sunshine temperature weather

Solution

hot → cold : warm → _____

Circle the word that fits best:

cool freezing sunshine temperature weather

Cold is the opposite of hot. Similarly, cool is the opposite of warm.

Please **wait** until you are told to begin.

Before Activities Assessment Questions

For each, circle the word that fits best.

1. kitchen → stove : garage → _____
alley car carport opener park
2. truck → train : taxi → _____
bus cab driver fare passenger
3. heart → veins : brain → _____
control head nerves smart think
4. leg → dog : wheel → _____
car rubber spin steer turn
5. ax → woodcutter : knife → _____
butter chef fork sharp slice
6. link → chain : page → _____
book dictionary paper print text
8. rattlesnake → earthworm : dolphin → _____
crocodile goldfish salmon shark whale
8. stairs → climb : airplane → _____
engine fly movie stewardess wings
9. bedspread → bed : rug → _____
carpet floor lies soft tile
10. pyramid → triangle : cube → _____
block dice ice parallelogram square

2. What's Missing?

After Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

hot → cold : warm → _____ (Read this as: Hot is to cold as warm is to _____.)

Circle the word that fits best:

cool freezing sunshine temperature weather

Solution

hot → cold : warm → _____

Circle the word that fits best:

cool freezing sunshine temperature weather

Cold is the opposite of hot. Similarly, cool is the opposite of warm.

Please **wait** until you are told to begin.

After Activities Assessment Questions

For each, circle the word that fits best.

1. wallet → money : bottle → _____
cap glass jar juice plastic
2. cow → goat : grasshopper → _____
ant field hop insect legs
3. toilet → sewer : mouth → _____
chew eat food stomach teeth
4. sand → beach : dirt → _____
garden rocks shovel sidewalk worms
5. rifle → hunter : rod → _____
bait cast fisherman lure reel
6. bead → necklace : brick → _____
block build cement mortar wall
7. eagle → hummingbird : horse → _____
dog elephant mouse pig rhinoceros
8. scissors → cut : pencil → _____
eraser paper pen wood write
9. tablecloth → table : blanket → _____
cozy person soft warm wrap
10. square → cube : triangle → _____
base dice height parallelogram pyramid

Before Activities Assessment Solutions

1. kitchen → stove : garage → _____
alley **car** carport opener park
2. truck → train : taxi → _____
bus cab driver fare passenger
3. heart → veins : brain → _____
control head **nerves** smart think
4. leg → dog : wheel → _____
car rubber spin steer turn
5. ax → woodcutter : knife → _____
butter **chef** fork sharp slice
6. link → chain : page → _____
book dictionary paper print text
7. rattlesnake → earthworm : dolphin → _____
crocodile **goldfish** salmon shark whale
8. stairs → climb : airplane → _____
engine **fly** movie stewardess wings
9. bedspread → bed : rug → _____
carpet **floor** lies soft tile
10. pyramid → triangle : cube → _____
block dice ice parallelogram **square**

After Activities Assessment Solutions

1. wallet → money : bottle → _____
cap glass jar **juice** plastic
2. cow → goat : grasshopper → _____
ant field hop insect legs
3. toilet → sewer : mouth → _____
chew eat food **stomach** teeth
4. sand → beach : dirt → _____
garden rocks shovel sidewalk worms
5. rifle → hunter : rod → _____
bait cast **fisherman** lure reel
6. bead → necklace : brick → _____
block build cement mortar **wall**
7. eagle → hummingbird : horse → _____
dog elephant **mouse** pig rhinoceros
8. scissors → cut : pencil → _____
eraser paper pen wood **write**
9. tablecloth → table : blanket → _____
cozy **person** soft warm wrap
10. square → cube : triangle → _____
base dice height parallelogram **pyramid**

3. What's Next?

Before Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

Fill in the next two numbers: 1 2 3 4 5 _____

Solution

1 2 3 4 5 6 7

Each number is one more than the preceding number.

Please **wait** until you are told to begin.

Before Activities Assessment Questions

Fill in the next two numbers in each series:

a) 5 8 11 14 17 _____

b) 7 10 14 19 25 _____

c) 60 48 38 30 24 _____

d) 4 7 11 14 18 _____

e) 27 24 19 16 11 _____

f) 24 28 22 26 20 _____

g) 12 9 13 10 14 _____

h) 6 8 80 82 820 _____

i) 5 3 9 7 21 _____

j) 48 56 28 36 18 _____

3. What's Next?

After Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

Example

Fill in the next two numbers: 1 2 3 4 5 _____

Solution

1 2 3 4 5 6 7

Each number is one more than the preceding number.

Please **wait** until you are told to begin.

After Activities Assessment Questions

Fill in the next two numbers in each series:

a) 4 7 10 13 16 _____

b) 6 9 13 18 24 _____

c) 50 38 28 20 14 _____

d) 5 8 12 15 19 _____

e) 28 25 20 17 12 _____

f) 34 38 32 36 30 _____

g) 11 8 12 9 13 _____

h) 4 6 60 62 620 _____

i) 6 4 12 10 30 _____

j) 40 48 24 32 16 _____

Before Activities Assessment Solutions

a) 5 8 11 14 17 $\boxed{20}$ $\boxed{23}$

b) 7 10 14 19 25 $\boxed{32}$ $\boxed{40}$

c) 60 48 38 30 24 $\boxed{20}$ $\boxed{18}$

d) 4 7 11 14 18 $\boxed{21}$ $\boxed{25}$

e) 27 24 19 16 11 $\boxed{8}$ $\boxed{3}$

f) 24 28 22 26 20 $\boxed{24}$ $\boxed{18}$

g) 12 9 13 10 14 $\boxed{11}$ $\boxed{15}$

h) 6 8 80 82 820 $\boxed{822}$ $\boxed{8220}$

i) 5 3 9 7 21 $\boxed{19}$ $\boxed{57}$

j) 48 56 28 36 18 $\boxed{26}$ $\boxed{13}$

After Activities Assessment Solutions

a) 4 7 10 13 16 $\boxed{19}$ $\boxed{22}$

b) 6 9 13 18 24 $\boxed{31}$ $\boxed{39}$

c) 50 38 28 20 14 $\boxed{10}$ $\boxed{8}$

d) 5 8 12 15 19 $\boxed{22}$ $\boxed{26}$

e) 28 25 20 17 12 $\boxed{9}$ $\boxed{4}$

f) 34 38 32 36 30 $\boxed{34}$ $\boxed{28}$

g) 11 8 12 9 13 $\boxed{10}$ $\boxed{14}$

h) 4 6 60 62 620 $\boxed{622}$ $\boxed{6220}$

i) 6 4 12 10 30 $\boxed{28}$ $\boxed{84}$

j) 40 48 24 32 16 $\boxed{24}$ $\boxed{12}$

4. Fitting In

Before Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

You can use a calculator.

Example

The following are yirgs: (“Yirgs” and other names like that are nonsensical.)

12 15 102 123 1234

The following are NOT yirgs:

21 51 202 323 2345

Of the numbers below, circle each one that is a yirg.

17 41 112 401 4321

Solution

The yirgs are highlighted below.

17 41 112 401 4321

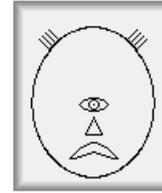
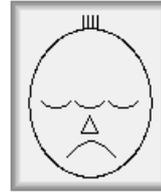
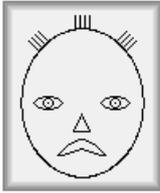
Each yirg begins with a “1”.

Please **wait** until you are told to begin.

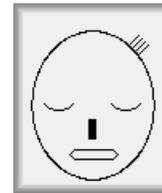
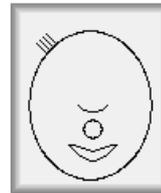
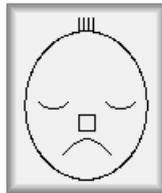
Before Activities Assessment Questions

Question 1

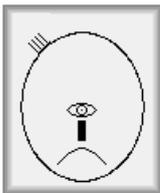
The following are harbs:



The following are NOT harbs:

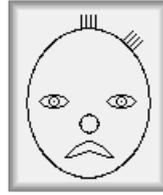


Of the following, circle each harb.

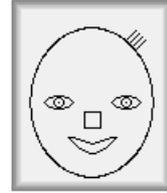
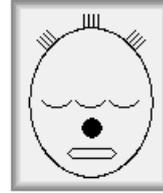
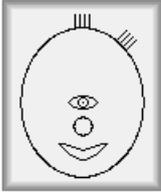


Question 2

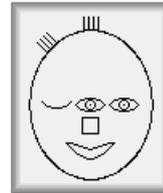
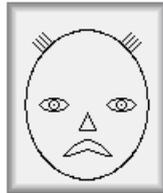
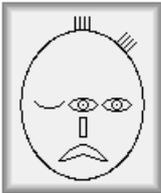
The following are fregs:



The following are NOT fregs:



Of the following, circle each freg.



Question 3

The following are manks:

a d g o p

The following are NOT manks:

c h l r s

Circle every letter below that is a mank.

b e f n z

Question 4

The following are duks:

A H M T Y

The following are NOT duks:

F J K P Q

Circle every letter below that is a duk.

G L O R X

Question 5

The following are murfs:

32 332 352 3182 3242

The following are NOT murfs:

213 432 353 1352 4242

Circle every number below that is a murf.

23 312 352 3522 4442

Question 6

The following are olgs:

45 342 423 504 540

The following are NOT olgs:

53 242 306 541 702

Circle every number below that is an olg.

54 243 422 604 612

Question 7

The following are knigs:

$\frac{4}{6}$ $\frac{3}{9}$ $\frac{12}{15}$ $\frac{10}{18}$ $\frac{7}{30}$

The following are NOT knigs:

$\frac{3}{8}$ $\frac{9}{16}$ $\frac{30}{32}$ $\frac{10}{35}$ $\frac{12}{40}$

Of the fractions below, circle each one that is a knig.

$\frac{3}{5}$ $\frac{5}{18}$ $\frac{12}{27}$ $\frac{15}{33}$ $\frac{24}{43}$

Question 8

The following are quisks:

$\frac{3}{4}$ $\frac{15}{25}$ $\frac{9}{36}$ $\frac{39}{64}$ $\frac{17}{81}$

The following are NOT quisks:

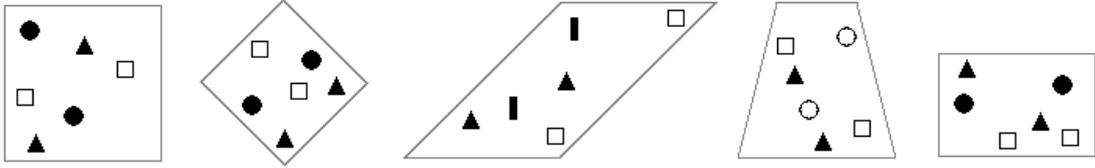
$\frac{5}{7}$ $\frac{16}{23}$ $\frac{14}{36}$ $\frac{17}{48}$ $\frac{53}{84}$

Of the fractions below, circle each one that is a quisk.

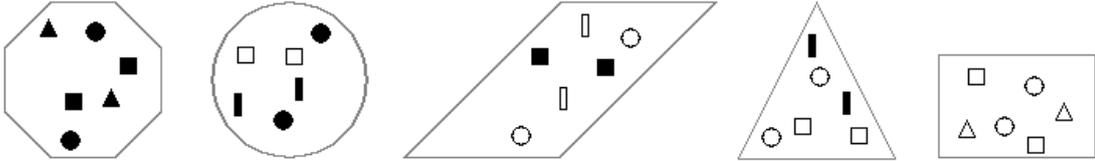
$\frac{7}{8}$ $\frac{3}{25}$ $\frac{5}{27}$ $\frac{7}{36}$ $\frac{24}{49}$

Question 9

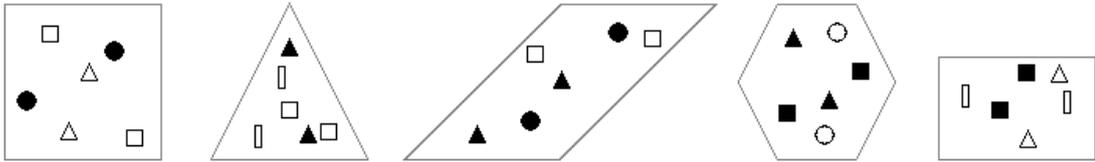
The following are kriffs:



The following are NOT kriffs:

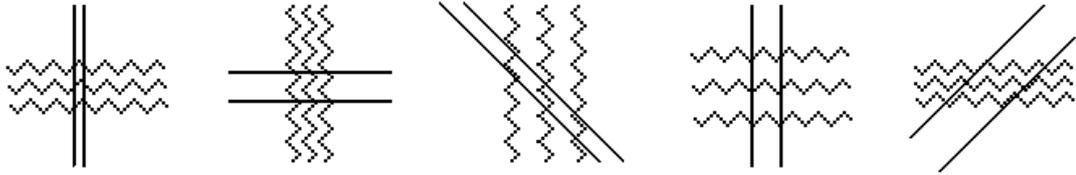


Of the following, circle each kriff.

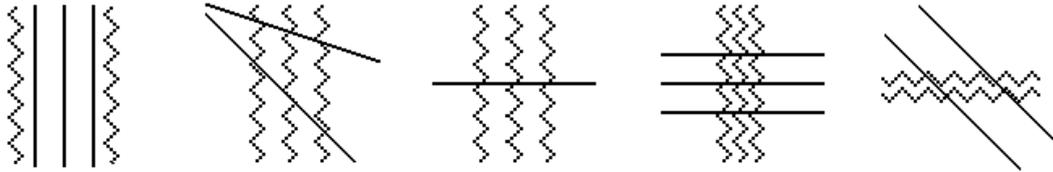


Question 10

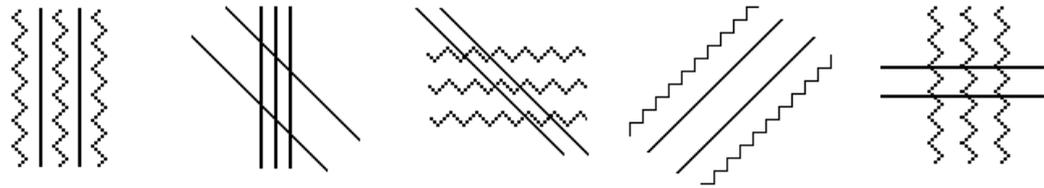
The following are spaps:



The following are NOT spaps:



Of the following, circle each spap.



4. Fitting In

After Activities Assessment

Instructions

Your results are not a part of any school mark.

There is no time limit.

Spend time thinking about each question. If you are stuck after trying hard, move on to the next question.

You can use a calculator.

Example

The following are yirgs: (“Yirgs” and other names like that are nonsensical.)

12 15 102 123 1234

The following are NOT yirgs:

21 51 202 323 2345

Of the numbers below, circle each one that is a yirg.

17 41 112 401 4321

Solution

The yirgs are highlighted below.

17 41 112 401 4321

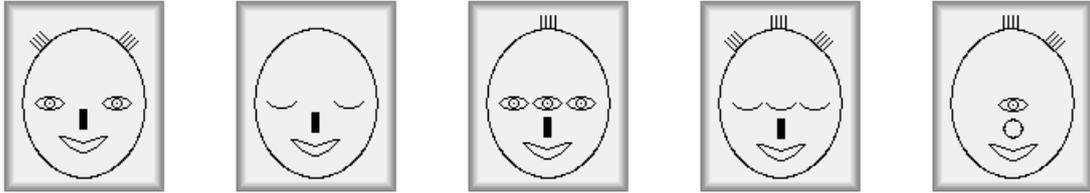
Each yirg begins with a “1”.

Please **wait** until you are told to begin.

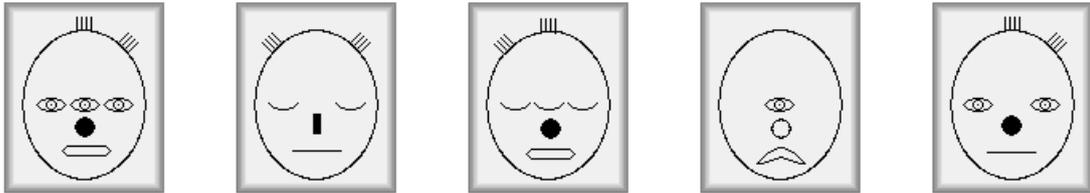
After Activities Assessment

Question 1

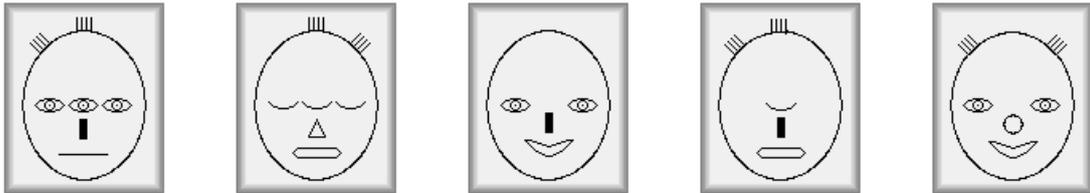
The following are jags:



The following are NOT jags:

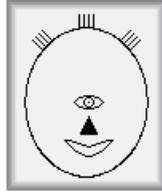
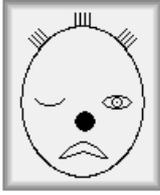


Of the following, circle each jag.

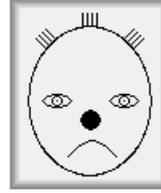
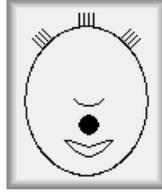


Question 2

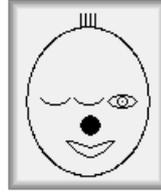
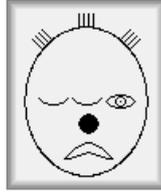
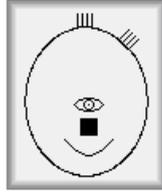
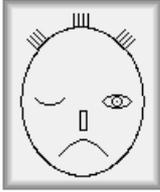
The following are worgs:



The following are NOT worgs:



Of the following, circle each worg.



Question 3

The following are korgs:

a b d g o

The following are NOT korgs:

c f h j v

Circle every letter below that is a korg.

e k m q t

Question 4

The following are gorks:

A H M U Y

The following are NOT gorks:

G J L P R

Circle every letter below that is a gork.

F J K V W

Question 5

The following are jubs:

43 433 453 4183 4243

The following are NOT jubs:

314 353 432 1452 5243

Circle every number below that is a jub.

34 483 453 4963 5553

Question 6

The following are ferds:

35 341 413 503 530

The following are NOT ferds:

54 242 352 351 701

Circle every number below that is a ferd.

53 233 423 513 533

Question 7

The following are lesks:

$\frac{4}{5}$ $\frac{9}{15}$ $\frac{14}{20}$ $\frac{7}{30}$ $\frac{25}{45}$

The following are NOT lesks:

$\frac{4}{8}$ $\frac{9}{14}$ $\frac{25}{33}$ $\frac{10}{36}$ $\frac{16}{49}$

Of the fractions below, circle each one that is a lesk.

$\frac{4}{9}$ $\frac{5}{15}$ $\frac{14}{24}$ $\frac{27}{35}$ $\frac{13}{50}$

Question 8

The following are horps:

$\frac{4}{9}$ $\frac{14}{16}$ $\frac{22}{36}$ $\frac{48}{49}$ $\frac{12}{81}$

The following are NOT horps:

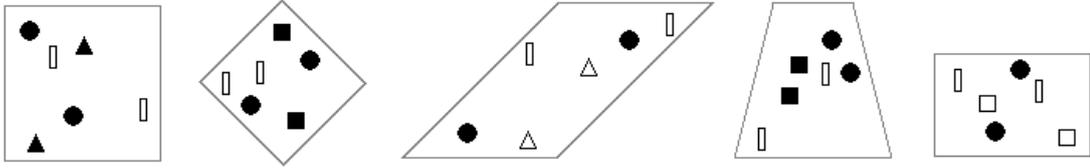
$\frac{4}{8}$ $\frac{18}{20}$ $\frac{15}{36}$ $\frac{32}{48}$ $\frac{21}{84}$

Of the fractions below, circle each one that is a horp.

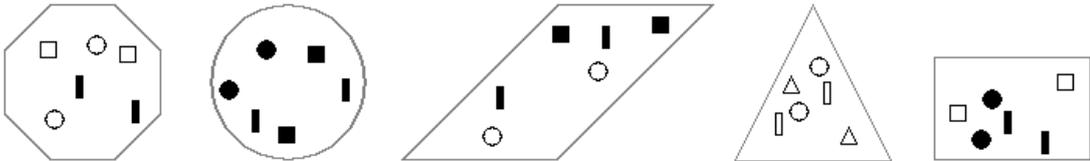
$\frac{6}{12}$ $\frac{17}{25}$ $\frac{8}{35}$ $\frac{12}{36}$ $\frac{28}{64}$

Question 9

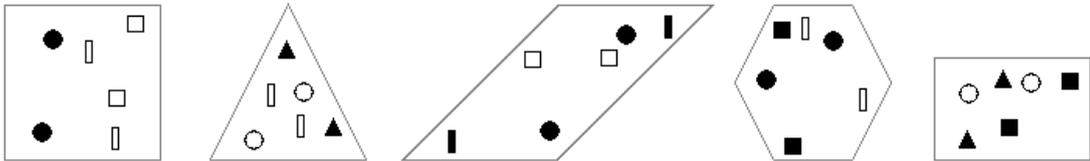
The following are bugs:



The following are NOT bugs:

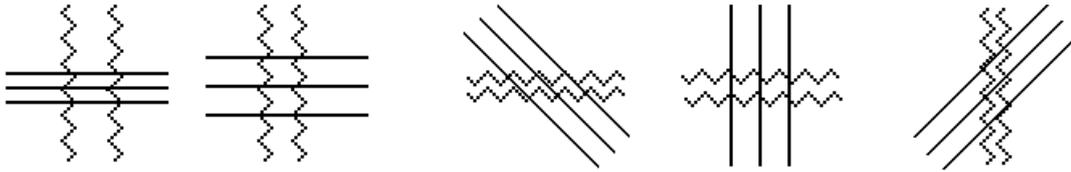


Of the following, circle each bug.

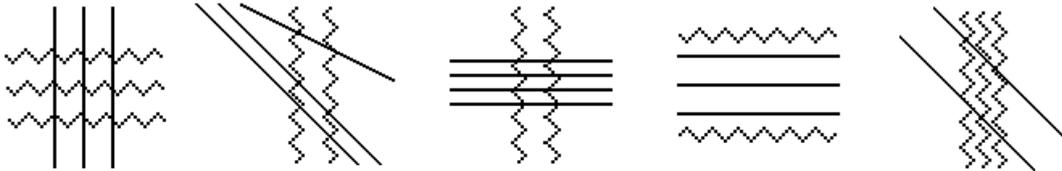


Question 10

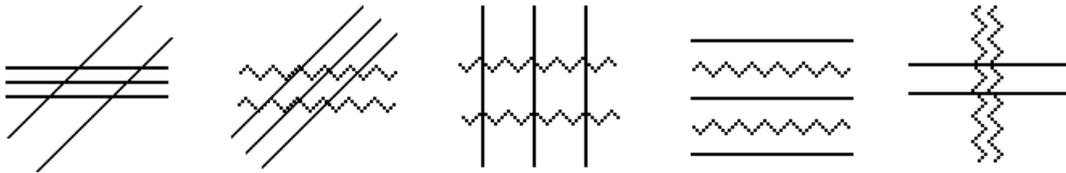
The following are ronks:



The following are NOT ronks:



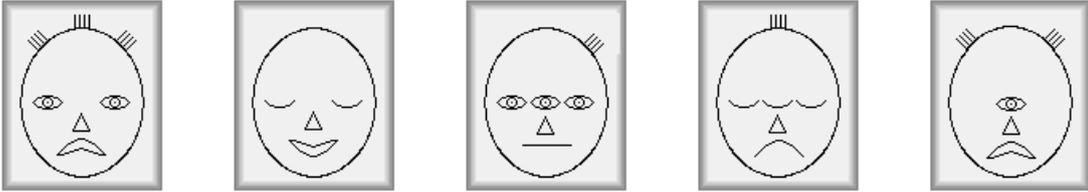
Of the following, circle each ronk.



Before Activities Assessment Solutions

Question 1 - Solution

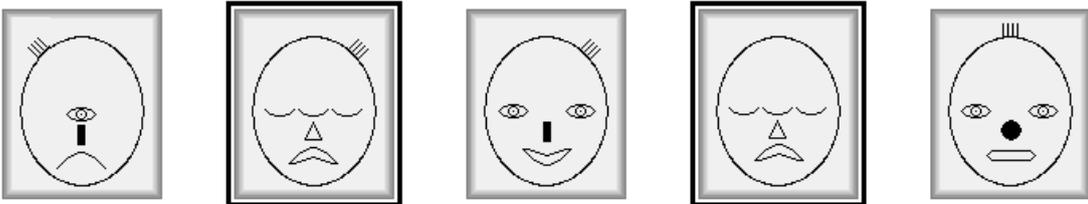
The following are harbs:



The following are NOT harbs:



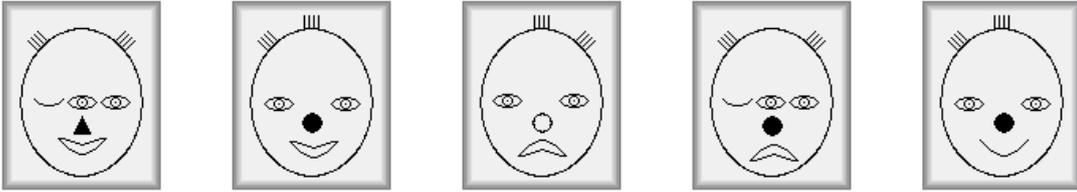
The harbs are highlighted below:



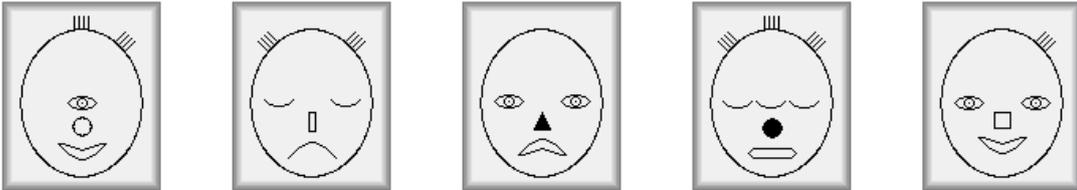
Harbs have an unfilled triangular nose.

Question 2 - Solution

The following are fregs:



The following are NOT fregs:



The fregs are highlighted below:



Fregs have two open eyes and hair in two places.

Question 3 – Solution

The following are manks:

a d g o p

The following are NOT manks:

c h l r s

Manks are:

b e f n z Enclosed space

Question 4 – Solution

The following are duks:

A H M T Y

The following are NOT duks:

F J K P Q

Duks are:

G L O R X Symmetrical

Question 5 – Solution

The following are murfs:

32 332 352 3182 3242

The following are NOT murfs:

213 432 353 1352 4242

Murfs are.

23 312 352 3522 4442 Begins with a 3 and ends with a 2.

Question 6 – Solution

The following are olgs:

45 342 423 504 540

The following are NOT olgs:

53 242 306 541 702

Olg are:

54 **243** 422 604 612

Digits add to 9 and the number has a “4” in it.

Question 7 – Solution

The following are knigs:

$\frac{4}{6}$ $\frac{3}{9}$ $\frac{12}{15}$ $\frac{10}{18}$ $\frac{7}{30}$

The following are NOT knigs:

$\frac{3}{8}$ $\frac{9}{16}$ $\frac{30}{32}$ $\frac{10}{35}$ $\frac{12}{40}$

Knigs are:

$\frac{3}{5}$ **$\frac{5}{18}$** **$\frac{12}{27}$** **$\frac{15}{33}$** $\frac{24}{43}$

Denominator evenly divisible by 3.

Question 8 – Solution

The following are quisks:

$\frac{3}{4}$ $\frac{15}{25}$ $\frac{9}{36}$ $\frac{39}{64}$ $\frac{17}{81}$

The following are NOT quisks:

$\frac{5}{7}$ $\frac{16}{23}$ $\frac{14}{36}$ $\frac{17}{48}$ $\frac{53}{84}$

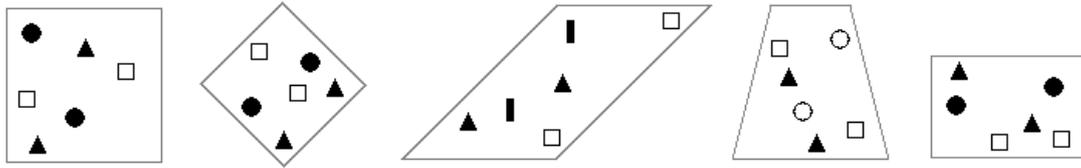
Quisks are:

$\frac{7}{8}$ **$\frac{3}{25}$** $\frac{5}{27}$ **$\frac{7}{36}$** $\frac{24}{49}$

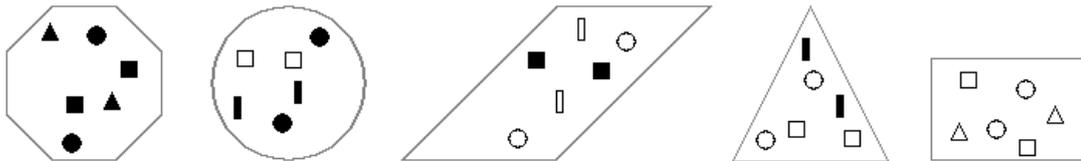
Odd numerator and perfect square denominator.

Question 9 - Solution

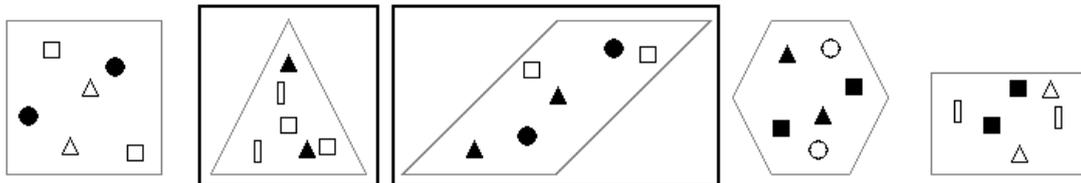
The following are kriffs:



The following are NOT kriffs:



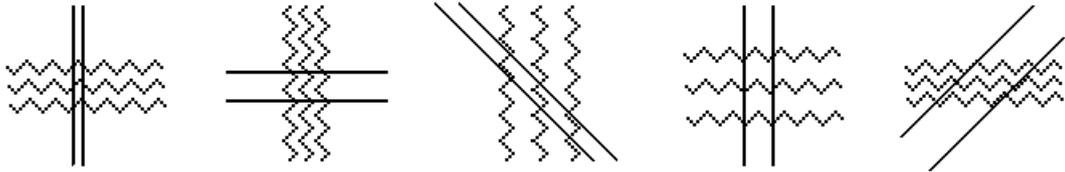
The kriffs are highlighted:



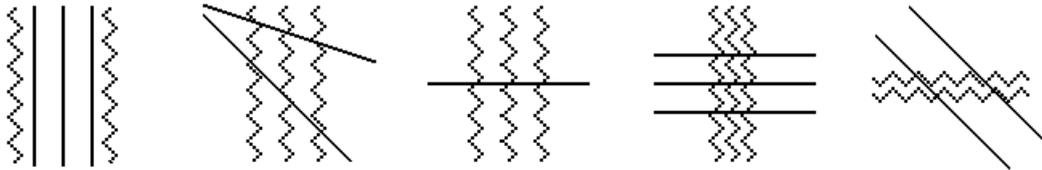
Kriffs contain 2 filled triangles and 2 empty squares.

Question 10 - Solution

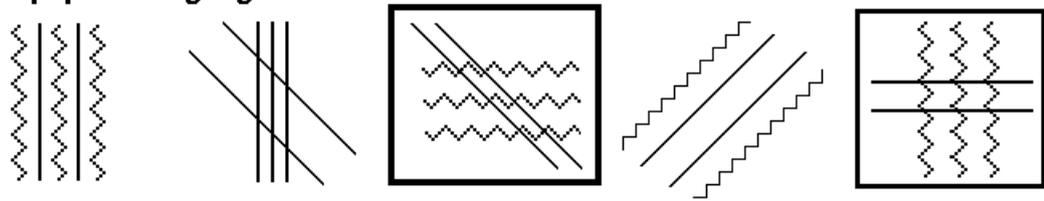
The following are spaps:



The following are NOT spaps:



The spaps are highlighted:

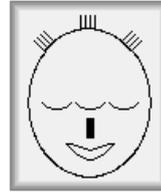
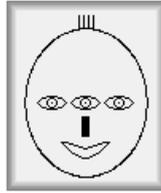
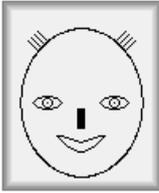


Spaps have 2 parallel straight lines intersecting with 3 jagged lines.

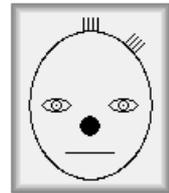
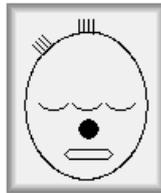
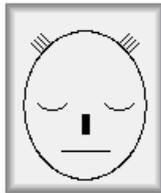
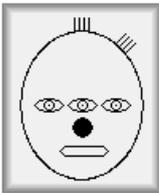
After Activities Assessment Solutions

Question 1 - Solution

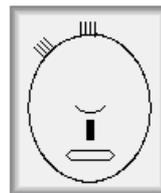
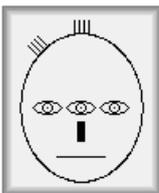
The following are jags:



The following are NOT jags:



The jags are highlighted below:



Jags have an open smile.

Question 2 - Solution

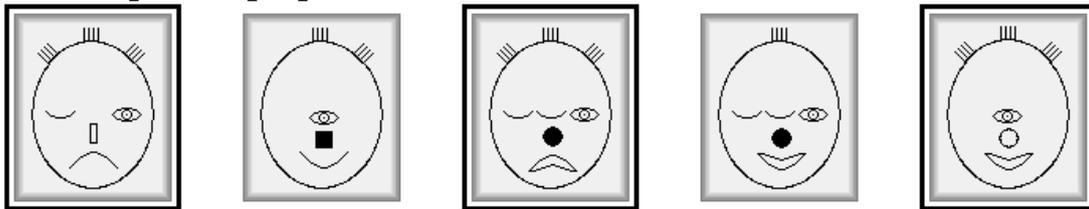
The following are worgs:



The following are NOT worgs:



The worgs are highlighted below:



Worgs have one eye open and hair in three places.

Question 3 – Solution

The following are korgs:

a b d g o

The following are NOT korgs:

c f h j v

Korgs are:

e k m q t Enclosed space

Question 4 – Solution

The following are gorks:

A H M U Y

The following are NOT gorks:

G J L P R

Gorks are:

F J K V W Symmetrical letters

Question 5 – Solution

The following are jubs:

43 433 453 4183 4243

The following are NOT jubs:

314 353 432 1452 5243

Jubs are:

34 483 453 4963 5553 Begins with a 4 and ends with a 3

Question 6 – Solution

The following are ferds:

35 341 413 503 530

The following are NOT ferds:

54 242 352 351 701

Ferds are:

53 **233** 423 513 533

Contains a 3 and digits add to 8

Question 7 – Solution

The following are lesks:

$\frac{4}{5}$ $\frac{9}{15}$ $\frac{14}{20}$ $\frac{7}{30}$ $\frac{25}{45}$

The following are NOT lesks:

$\frac{4}{8}$ $\frac{9}{14}$ $\frac{25}{33}$ $\frac{10}{36}$ $\frac{16}{49}$

Lesks are:

$\frac{4}{9}$ **$\frac{5}{15}$** $\frac{14}{24}$ **$\frac{27}{35}$** **$\frac{13}{50}$**

Denominator evenly divisible by 5

Question 8 – Solution

The following are horps:

$\frac{4}{9}$ $\frac{14}{16}$ $\frac{22}{36}$ $\frac{48}{49}$ $\frac{12}{81}$

The following are NOT horps:

$\frac{4}{8}$ $\frac{18}{20}$ $\frac{15}{36}$ $\frac{32}{48}$ $\frac{21}{84}$

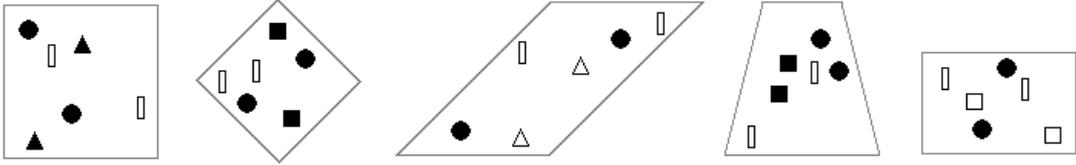
Horps are:

$\frac{6}{12}$ $\frac{17}{25}$ $\frac{8}{35}$ **$\frac{12}{36}$** **$\frac{28}{64}$**

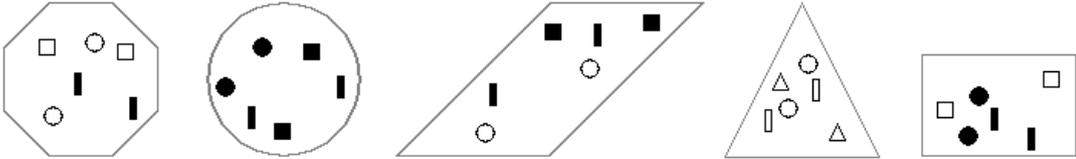
Even numerator, perfect square denom.

Question 9 - Solution

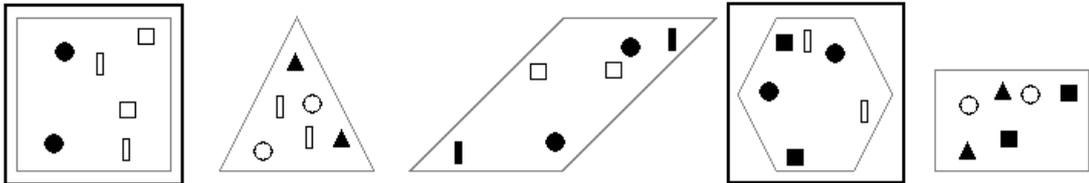
The following are bugs:



The following are NOT bugs:



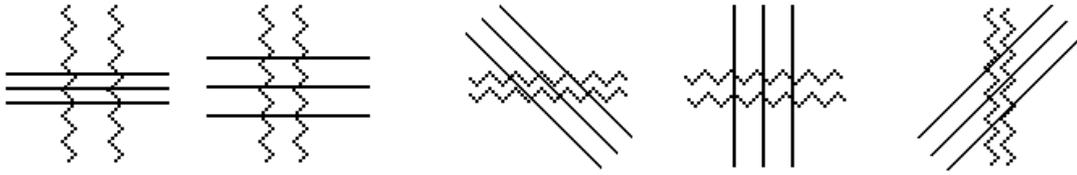
The bugs are highlighted:



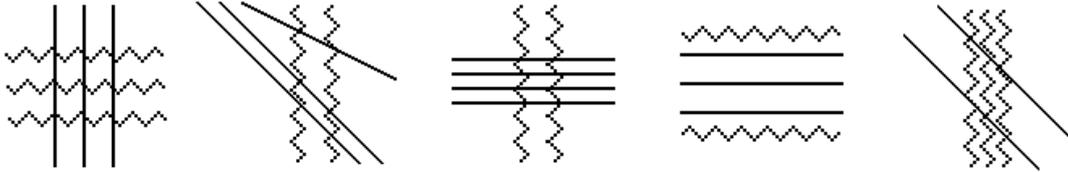
Bugs contain 2 filled circles and 2 empty rectangles.

Question 10 - Solution

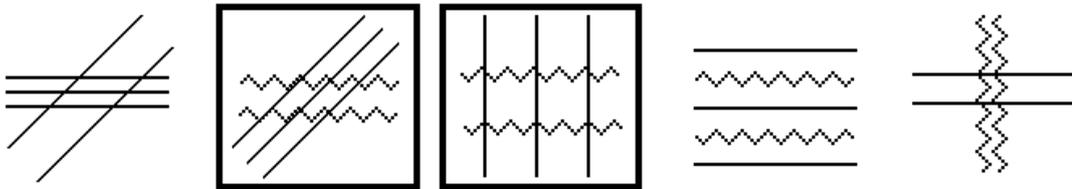
The following are ronks:



The following are NOT ronks:



The ronks are highlighted:



Ronks have 3 parallel straight lines intersecting with 2 jagged lines.

5. Clues

Before Activities Assessment

Instructions

Your results are not a part of any school mark. There is no time limit. Spend time thinking about each question. If you are stuck after trying hard, try the next question.

To solve “clues” problems:

- Read and understand the problem.
- Each problem gives you initial clues. Based on each clue, place a “Yes”, for “Yes, the clue says so”, or “No”, for “No, the clue says it isn’t”, into the matrix.
- Based on the problem and the partially filled in matrix, use logic to make one or more conclusions. For each conclusion, place a “Yes” or “No” into the matrix. Repeat this until the matrix is filled.

Example

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow			
Elizabeth Swann			

If you are told that each person has one different favourite food and Captain Jack Sparrow prefers rice, you could place a “Yes” in the matrix as shown below.

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow			Yes
Elizabeth Swann			

In your next step, you could place a “No” in the Captain Jack Sparrow-Potato box because potatoes would NOT be Captain Jack Sparrow’s favourite food.

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow		No	Yes
Elizabeth Swann			

You continue in the same way to fill the matrix and use other given information.

Please **wait** until you are told to begin.

Before Activities Assessment Questions

Question 1

	May	July	August	December
Cheshire				
Felix				
Sylvester				
Tigger				

Cheshire, Felix, Sylvester, and Tigger each have a different favourite month. Given:

- Felix's favourite month is July.
- Sylvester's favourite month is NOT August or December.
- Tigger's favourite month is NOT August.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Month
Cheshire	
Felix	
Sylvester	
Tigger	

Question 2

	Jupiter	Saturn	Uranus	Neptune
Coach Kleats				
Miss Grundy				
Mr. Flutesnoot				
Mr. Weatherbee				

Coach Kleats, Miss Grundy, Mr. Flutesnoot, and Mr. Weatherbee each have a different favourite gas giant planet. Given:

- Miss Grundy's favourite gas giant planet is Uranus.
- Saturn is NOT the favourite gas giant planet of Coach Kleats or Mr. Flutesnoot.
- Mr. Flutesnoot's favourite gas giant planet is NOT Neptune.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Gas Giant Planet
Coach Kleats	
Miss Grundy	
Mr. Flutesnoot	
Mr. Weatherbee	

Question 3

	Grizzly Bear	Polar Bear	Spirit Bear		Bobcat	Cougar	Lynx
Spongebob							
Patrick							
Squidward							

Spongebob, Patrick, and Squidward all want to travel to Canada to see a different favourite bear and cat. Given:

- Patrick's favourite bear is a spirit bear. His favourite cat is NOT the lynx.
- A grizzly bear is NOT Squidward's favourite bear. His favourite cat is the bobcat.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Bear	Favourite Cat
Spongebob		
Patrick		
Squidward		

Question 4

	Batman	The Hulk	Spiderman	Superman		Morning	Afternoon	Evening	Night
Bart									
Homer									
Lisa									
Marge									

Bart, Homer, Lisa, and Marge each have a different favourite comic book hero and time to read comics. Given:

- Bart's favourite comic book hero is NOT Spiderman. He prefers to read comics in the evening.
- Homer's favourite comic book hero is Batman. He does NOT like to read comics in the morning or night.
- Lisa's favourite comic book hero is NOT Spiderman or Superman.
- Marge does NOT like to read comics in the night.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Comic Book Hero	Favourite Time to Read Comics
Bart		
Homer		
Lisa		
Marge		

Question 5

	5:00	6:00	7:00	8:00
Bugs				
Daffy				
Donald				
Mickey				

Bugs, Daffy, Donald, and Mickey each have a different preferred time to have dinner.

Given:

- Daffy prefers dinner later than 6:30.
- Donald likes to have dinner later than Daffy.
- Mickey does NOT like to have dinner at 6:00.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Preferred Time for Dinner
Bugs	
Daffy	
Donald	
Mickey	

Question 6

	2 books	3 books	4 books	5 books
Donkey				
Lord Farquaad				
Princess Fiona				
Shrek				

Donkey, Lord Farquaad, Princess Fiona, and Shrek each read a different number of books last month. How many books did each read if:

- Donkey read more than 3 books.
- Lord Farquaad read more than 3 books.
- Shrek did NOT read the most or least number of books.
- Donkey did NOT read 4 books.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Books Read Last Month
Donkey	
Lord Farquaad	
Princess Fiona	
Shrek	

Question 7

	3 touchdowns	4 touchdowns	5 touchdowns	6 touchdowns
Tom Brady				
Drew Brees				
Eli Manning				
Tony Romo				

Brady, Brees, Manning, and Romo each threw different number of touchdowns during the first game of the season. Given:

- Brees threw more touchdowns than Romo.
- Manning did NOT throw the fewest touchdowns.
- Romo threw more than 4 touchdowns.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Person	Number of Touchdowns
Tom Brady	
Drew Brees	
Eli Manning	
Tony Romo	

Question 8

	5 times	6 times	7 times	8 times
Aslan				
Digory Kirke				
Jadis				
Mr. Tumnus				

Last month, Aslan, Digory Kirke, Jadis, and Mr. Tumnus each helped a charitable organization a different number of times. How many times did each help a charitable organization if:

- Mr. Tumnus helped a charitable organization fewer times than Aslan.
- Digory Kirke helped a charitable organization fewer times than Mr. Tumnus.
- Aslan did NOT help a charitable organization the most number of times.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Times He/She Helped a Charitable Organization
Aslan	
Digory Kirke	
Jadis	
Mr. Tumnus	

Question 9

	2 coins	3 coins	4 coins	6 coins
Joey				
Monica				
Phoebe				
Rachel				

Joey, Monica, Phoebe, and Rachel have 2, 3, 4, or 6 coins. Each has a different number of coins. Given:

- Monica has half the number of coins as Phoebe.
- Rachel has the least number of coins.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Number of Coins
Joey	
Monica	
Phoebe	
Rachel	

Question 10

	2 pennies	4 pennies	6 pennies	12 pennies
Elaine				
George				
Jerry				
Kramer				

Elaine, George, Jerry, and Kramer have 2, 4, 6, or 12 pennies. Each has a different number of pennies. Given:

- Kramer has three times the number of pennies as Jerry.
- Elaine has more pennies than Kramer.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Number of Pennies
Elaine	
George	
Jerry	
Kramer	

5. Clues

After Activities Assessment

Instructions

Your results are not a part of any school mark. There is no time limit. Spend time thinking about each question. If you are stuck after trying hard, try the next question.

To solve “clues” problems:

- Read and understand the problem.
- Each problem gives you initial clues. Based on each clue, place a “Yes”, for “Yes, the clue says so”, or “No”, for “No, the clue says it isn’t”, into the matrix.
- Based on the problem and the partially filled in matrix, use logic to make one or more conclusions. For each conclusion, place a “Yes” or “No” into the matrix. Repeat this until the matrix is filled.

Example

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow			
Elizabeth Swann			

If you are told that each person has one different favourite food and Captain Jack Sparrow prefers rice, you could place a “Yes” in the matrix as shown below.

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow			Yes
Elizabeth Swann			

In your next step, you could place a “No” in the Captain Jack Sparrow-Potato box because potatoes would NOT be Captain Jack Sparrow’s favourite food.

	Pasta	Potato	Rice
Captain Barbossa			
Captain Jack Sparrow		No	Yes
Elizabeth Swann			

You continue in the same way to fill the matrix and use other given information.

Please **wait** until you are told to begin.

After Activities Assessment Questions

Question 1

	May	July	August	December
Cheshire				
Felix				
Sylvester				
Tigger				

Cheshire, Felix, Sylvester, and Tigger each have a different favourite month. Given:

- Cheshire's favourite month is NOT July.
- Felix's favourite month is NOT May or July.
- Sylvester's favourite month is August.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Month
Cheshire	
Felix	
Sylvester	
Tigger	

Question 2

	Callisto	Europa	Ganymede	Io
Coach Kleats				
Miss Grundy				
Mr. Flutesnoot				
Mr. Weatherbee				

Coach Kleats, Miss Grundy, Mr. Flutesnoot, and Mr. Weatherbee each have a different favourite moon of Jupiter. Given:

- Mr. Flutesnoot's favourite moon of Jupiter is Europa.
- Callisto is NOT the favourite moon of Jupiter of Coach Kleats or Mr. Weatherbee.
- Mr. Weatherbee's favourite moon of Jupiter is NOT Io.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Moon of Jupiter
Coach Kleats	
Miss Grundy	
Mr. Flutesnoot	
Mr. Weatherbee	

Question 3

	Grizzly Bear	Polar Bear	Spirit Bear		Bobcat	Cougar	Lynx
Spongebob							
Patrick							
Squidward							

Spongebob, Patrick, and Squidward all want to travel to Canada to see a different favourite bear and cat. Given:

- Spongebob's favourite bear is a grizzly bear. His favourite cat is NOT the bobcat.
- A spirit bear is NOT Patrick's favourite bear. His favourite cat is the lynx.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Bear	Favourite Cat
Spongebob		
Patrick		
Squidward		

Question 4

	Batman	The Hulk	Spider-man	Superman		Morning	Afternoon	Evening	Night
Bart									
Homer									
Lisa									
Marge									

Bart, Homer, Lisa, and Marge each have a different favourite comic book hero and time to read comics. Given:

- Bart's favourite comic book hero is The Hulk. He does NOT like to read comics in the afternoon or evening.
- Homer's favourite comic book hero is NOT Superman.
- Lisa's favourite time to read comics is in the morning.
- Marge does NOT like to read Batman or Superman. She does NOT like to read comics in the evening.

Use logic to fill in the matrix with a "Yes" or "No" for any conclusion you can make.

Answer:

Character	Favourite Comic Book Hero	Favourite Time to Read Comics
Bart		
Homer		
Lisa		
Marge		

Question 5

	5:00	6:00	7:00	8:00
Bugs				
Daffy				
Donald				
Mickey				

Bugs, Daffy, Donald, and Mickey each have a different preferred time to have dinner.

Given:

- Daffy prefers dinner earlier than 6:30.
- Donald likes to have dinner earlier than Daffy.
- Mickey does NOT like to have dinner at 7:00.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Preferred Time for Dinner
Bugs	
Daffy	
Donald	
Mickey	

Question 6

	2 comics	3 comics	4 comics	5 comics
Pumbaa				
Scar				
Simba				
Timon				

Pumbaa, Scar, Simba, and Timon each read a different number of comics today. How many comics did each read if:

- Pumbaa did NOT read the most or least number of comics.
- Simba read less than 4 comics.
- Timon read less than 4 comics.
- Timon did NOT read 3 comics.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Comics Read Today
Pumbaa	
Scar	
Simba	
Timon	

Question 7

	40 goals	42 goals	44 goals	46 goals
Sidney Crosby				
Pavel Datsyuk				
Evgeni Malkin				
Alexander Ovechkin				

Crosby, Datsyuk, Malkin, and Ovechkin have each scored a different number of goals.

Given:

- Malkin scored fewer goals than Crosby.
- Datsyuk did NOT score the most goals.
- Crosby scored fewer than 44 goals.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Person	Number of Goals
Sidney Crosby	
Pavel Datsyuk	
Evgeni Malkin	
Alexander Ovechkin	

Question 8

	6 times	7 times	8 times	9 times
Edmond				
Lucy				
Peter				
Susan				

In a trip to Narnia, Edmond, Lucy, Peter, and Susan were each in danger a different number of times. How many times was each in danger if:

- Susan was in danger more times than Edmond.
- Lucy was in danger more times than Susan.
- Edmond was NOT in danger the least number of times.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Times in Danger
Edmond	
Lucy	
Peter	
Susan	

Question 9

	2 coins	3 coins	4 coins	6 coins
Chandler				
Monica				
Phoebe				
Ross				

Chandler, Monica, Phoebe, and Ross have 2, 3, 4, or 6 coins. Each has a different number of coins. Given:

- Phoebe has half the number of coins as Monica.
- Chandler has the least number of coins.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Number of Coins
Chandler	
Monica	
Phoebe	
Ross	

Question 10

	2 pennies	4 pennies	6 pennies	12 pennies
Elaine				
George				
Jerry				
Kramer				

Elaine, George, Jerry, and Kramer have 2, 4, 6, or 12 pennies. Each has a different number of pennies. Given:

- Jerry has three times the number of pennies as George.
- Elaine has fewer pennies than George.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Number of Pennies
Elaine	
George	
Jerry	
Kramer	

Before Activities Assessment Solutions

Question 1

	May	July	August	December
Cheshire	No	No	Yes	No
Felix	No	Yes	No	No
Sylvester	Yes	No	No	No
Tigger	No	No	No	Yes

Character	Favourite Month
Cheshire	August
Felix	July
Sylvester	May
Tigger	December

Question 2

	Jupiter	Saturn	Uranus	Neptune
Coach Kleats	No	No	No	Yes
Miss Grundy	No	No	Yes	No
Mr. Flutesnoot	Yes	No	No	No
Mr. Weatherbee	No	Yes	No	No

Character	Favourite Gas Giant Planet
Coach Kleats	Neptune
Miss Grundy	Uranus
Mr. Flutesnoot	Jupiter
Mr. Weatherbee	Saturn

Question 3

	Grizzly Bear	Polar Bear	Spirit Bear		Bobcat	Cougar	Lynx
Spongebob	Yes	No	No		No	No	Yes
Patrick	No	No	Yes		No	Yes	No
Squidward	No	Yes	No		Yes	No	No

Character	Favourite Bear	Favourite Cat
Spongebob	grizzly bear	lynx
Patrick	spirit bear	cougar
Squidward	polar bear	bobcat

Question 4

	Batman	The Hulk	Spider-man	Super-man		Morning	Afternoon	Evening	Night
Bart	No	No	No	Yes		No	No	Yes	No
Homer	Yes	No	No	No		No	Yes	No	No
Lisa	No	Yes	No	No		No	No	No	Yes
Marge	No	No	Yes	No		Yes	No	No	No

Character	Favourite Comic Book Hero	Favourite Time to Read Comics
Bart	Superman	evening
Homer	Batman	afternoon
Lisa	The Hulk	night
Marge	Spiderman	morning

Question 5

	5:00	6:00	7:00	8:00
Bugs	No	Yes	No	No
Daffy	No	No	Yes	No
Donald	No	No	No	Yes
Mickey	Yes	No	No	No

Character	Preferred Time for Dinner
Bugs	6:00
Daffy	7:00
Donald	8:00
Mickey	5:00

Question 6

	2 books	3 books	4 books	5 books
Donkey	N	N	N	Y
Lord Farquaad	N	N	Y	N
Princess Fiona	Y	N	N	N
Shrek	N	Y	N	N

Character	Books Read Last Month
Donkey	5
Lord Farquaad	4
Princess Fiona	2
Shrek	3

Question 7

	3 touchdowns	4 touchdowns	5 touchdowns	6 touchdowns
Tom Brady	Y	N	N	N
Drew Brees	N	N	N	Y
Eli Manning	N	Y	N	N
Tony Romo	N	N	Y	N

Person	Number of Touchdowns
Tom Brady	3
Drew Brees	6
Eli Manning	4
Tony Romo	5

Question 8

	5 times	6 times	7 times	8 times
Aslan	No	No	Yes	No
Digory Kirke	Yes	No	No	No
Jadis	No	No	No	Yes
Mr. Tumnus	No	Yes	No	No

Character	Times He/She Helped a Charitable Organization
Aslan	7
Digory Kirke	5
Jadis	8
Mr. Tumnus	6

Question 9

	2 coins	3 coins	4 coins	6 coins
Joey	No	No	Yes	No
Monica	No	Yes	No	No
Phoebe	No	No	No	Yes
Rachel	Yes	No	No	No

Character	Number of Coins
Joey	4
Monica	3
Phoebe	6
Rachel	2

Question 10

	2 pennies	4 pennies	6 pennies	12 pennies
Elaine	No	No	No	Yes
George	No	Yes	No	No
Jerry	Yes	No	No	No
Kramer	No	No	Yes	No

Character	Number of Pennies
Elaine	12
George	4
Jerry	2
Kramer	6

After Activities Assessment Solutions

Question 1

	May	July	August	December
Cheshire	Yes	No	No	No
Felix	No	No	No	Yes
Sylvester	No	No	Yes	No
Tigger	No	Yes	No	No

Character	Favourite Month
Cheshire	May
Felix	December
Sylvester	August
Tigger	July

Question 2

	Callisto	Europa	Ganymede	Io
Coach Kleats	No	No	No	Yes
Miss Grundy	Yes	No	No	No
Mr. Flutesnoot	No	Yes	No	No
Mr. Weatherbee	No	No	Yes	No

Character	Favourite Moon of Jupiter
Coach Kleats	Io
Miss Grundy	Callisto
Mr. Flutesnoot	Europa
Mr. Weatherbee	Ganymede

Question 3

	Grizzly Bear	Polar Bear	Spirit Bear		Bobcat	Cougar	Lynx
Spongebob	Yes	No	No		No	Yes	No
Patrick	No	Yes	No		No	No	Yes
Squidward	No	No	Yes		Yes	No	No

Character	Favourite Bear	Favourite Cat
Spongebob	grizzly bear	cougar
Patrick	polar bear	lynx
Squidward	spirit bear	bobcat

Question 4

	Batman	The Hulk	Spider-man	Super-man		Morning	Afternoon	Evening	Night
Bart	No	Yes	No	No		No	No	No	Yes
Homer	Yes	No	No	No		No	No	Yes	No
Lisa	No	No	No	Yes		Yes	No	No	No
Marge	No	No	Yes	No		No	Yes	No	No

Character	Favourite Comic Book Hero	Favourite Time to Read Comics
Bart	The Hulk	night
Homer	Batman	evening
Lisa	Superman	morning
Marge	Spiderman	afternoon

Question 5

	5:00	6:00	7:00	8:00
Bugs	No	No	Yes	No
Daffy	No	Yes	No	No
Donald	Yes	No	No	No
Mickey	No	No	No	Yes

Character	Preferred Time for Dinner
Bugs	7:00
Daffy	6:00
Donald	5:00
Mickey	8:00

Question 6

	2 comics	3 comics	4 comics	5 comics
Pumbaa	N	N	Y	N
Scar	N	N	N	Y
Simba	N	Y	N	N
Timon	Y	N	N	N

Character	Comics Read Today
Pumbaa	4
Scar	5
Simba	3
Timon	2

Question 7

	40 goals	42 goals	44 goals	46 goals
Sidney Crosby	N	Y	N	N
Pavel Datsyuk	N	N	Y	N
Evgeni Malkin	Y	N	N	N
Alexander Ovechkin	N	N	N	Y

Person	Number of Goals
Sidney Crosby	42
Pavel Datsyuk	44
Evgeni Malkin	40
Alexander Ovechkin	46

Question 8

	6 times	7 times	8 times	9 times
Edmond	No	Yes	No	No
Lucy	No	No	No	Yes
Peter	Yes	No	No	No
Susan	No	No	Yes	No

Character	Times in Danger
Edmond	7
Lucy	9
Peter	6
Susan	8

Question 9

	2 coins	3 coins	4 coins	6 coins
Chandler	Yes	No	No	No
Monica	No	No	No	Yes
Phoebe	No	Yes	No	No
Ross	No	No	Yes	No

Character	Number of Coins
Chandler	2
Monica	6
Phoebe	3
Ross	4

Question 10

	2 pennies	4 pennies	6 pennies	12 pennies
Elaine	Yes	No	No	No
George	No	Yes	No	No
Jerry	No	No	No	Yes
Kramer	No	No	Yes	No

Character	Number of Pennies
Elaine	2
George	4
Jerry	12
Kramer	6

SAMPLE LESSON MATERIAL

The sample materials in this appendix illustrate the instructional design strategies of the interventions. Note that what is presented below, does not necessarily show screen/page design. For example, an answer was usually presented on the next screen or page.

Classification Skill – Sample

Sample 1 – Step 1

Given: finger palm thumb

- a. arm b. hand c. hold d. knuckle e. wrist

Step 1: Determine what is common between the three given words.

Turn the page when you have thought of what they have in common.

Sample 1 – Step 1 Answer

Given: finger palm thumb

- a. arm b. hand c. hold d. knuckle e. wrist

Step 1: Determine what is common between the three given words.

All are a part of a hand.

Sample 1 – Step 2

Given: finger palm thumb

a. arm b. hand c. hold d. knuckle e. wrist

Step 1: Determine what is common between the three given words.

All are a part of a hand.

Step 2: From the answer choices, find a word that has the same thing in common.

Turn the page when you have thought of the word.

Sample 1 – Step 2 Answer

Given: finger palm thumb

a. arm b. hand c. hold d. **knuckle** e. wrist

Step 1: Determine what is common between the three given words.

All are a part of a hand.

Step 2: From the answer choices, find a word that has the same thing in common.

A knuckle is also part of a hand. An arm, hand, and wrist are not parts of a hand.

Classification Skill – Activity

Question 1

Given: buttonhole cuff sleeve

a. clothes b. collar c. cotton d. size e. tie

Hint 1:

Step 1: Determine what is common between the three given words.

Step 2: From the answer choices, find a word that has the same thing in common.
If more than one word has the same thing in common, repeat step 1.

Hint 2:

Each given word can be a part of a shirt. From the choices, find a word that can also be a part of a shirt.

Question 1 – Solution

Given: buttonhole cuff sleeve

a. clothes b. **collar** c. cotton d. size e. tie

Collar and each given word can be a part of a shirt.

Classification Skill – Summary

Summary

To solve “One For All and All For One” questions:

Step 1: Determine what is common between the three given words.

Step 2: From the answer choices, find a word that has the same thing in common.
If more than one word has the same thing in common, repeat step 1.

The fourth word will match for one of many possible reasons. For example, the words could have similar meanings (synonyms), be parts of the same object, or be examples of something.

Classification Skill – Self-test

Question 1

Given: blanket pillow sheets

- a. bed b. mattress c. night d. sleep e. snore

Question 1 – Solution

Given: blanket pillow sheets

- a. bed b. **mattress** c. night d. sleep e. snore

Mattress and each given word are a part of a bed.

Classification Skill – Challenge for Experts

Question 1

Given: airplane balloon helicopter

- a. air b. gas c. propeller d. rocket e. sky

Hint 1:

Step 1: Determine what is common between the three given words.

Step 2: From the answer choices, find a word that has the same thing in common.

If more than one word has the same thing in common, repeat step 1.

Hint 2:

Each given word is something that can travel in the air.

Question 1 – Solution

Given: airplane balloon helicopter

- a. air b. gas c. propeller d. **rocket** e. sky

Rocket and each given word are objects that can travel in the air.

Analogical Reasoning Skill – Sample

Sample 1 – Step 1

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words (hot and cold).

Turn the page when you have thought of a relationship.

Sample 1 – Step 1 Answer

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Antonyms are words with opposite or nearly opposite meanings.

Sample 1 – Step 2

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Turn the page when you have thought of a sentence.

Sample 1 – Step 2 Answer

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Compare your sentence with:

Hot is the opposite of cold.

Sample 1 – Step 3

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Hot is the opposite of cold.

Step 3: Create a similar sentence using the first word of the second pair.

Turn the page when you have thought of a sentence.

Sample 1 – Step 3 Answer

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Hot is the opposite of cold.

Step 3: Create a similar sentence using the first word of the second pair.

Compare your sentence with:

On is the opposite of _____.

Sample 1 – Step 4

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Hot is the opposite of cold.

Step 3: Create a similar sentence using the first word of the second pair.

On is the opposite of _____.

Step 4: With that sentence, circle the word below that best fits the given words:

Given: hot → cold : on → _____

light off power top working

Sample 1 – Step 4 Answer

Given: hot → cold : on → _____

Step 1: Determine the relationship between the first pair of words.

The words are opposites.

Step 2: Create a sentence with the first pair of words.

Hot is the opposite of cold.

Step 3: Create a similar sentence using the first word of the second pair.

On is the opposite of _____.

Step 4: With that sentence, circle the word below that best fits the given words:

Given: hot → cold : on → _____

light **off** power top working

Off is the best answer. On is the opposite of off. None of the other words are opposites of “on”.

Analogical Reasoning Skill – Activity

Question 1

Given:

big → small : heavy → _____

Circle the word that fits best:

bulky feathers light tiny weight

Hint 1:

- Determine the relationship between the first pair of words.
- Use the relationship to create a sentence with those two words.
- Use that idea to find the missing word.

Hint 2:

The relationship is that the first pair of words are opposites. A sentence could be:

Big is the opposite of small. Try this:

- Create a similar sentence using the first word of the second pair.
- Use that sentence to find the missing word.

Question 1 – Solution

Given:

big → small : heavy → _____

The word that fits best is highlighted below:

bulky feathers **light** tiny weight

The relationship is that the words are opposites (or antonyms). So, use a sentence such as:

Heavy is the opposite of _____. The word that fits best is “light”.

Analogical Reasoning Skill – Summary

Summary

To solve “What’s Missing?” questions:

Step 1: Determine the relationship between the first pair of words.

Step 2: Create a sentence with the first pair of words.

Step 3: Create a similar sentence using the first word of the second pair.

Step 4: Use that sentence to see which word in the list fits best.

The pairs of words will match for one of many possible reasons. For example, the words could be opposites or similar things. As well, word pairs could relate to where things are kept, what things hit other things, physical connections, parts of a whole, tools used, amounts of things, sizes, and so on.

Analogical Reasoning Skill – Self-test

Question 1

Given:

north → south : strong → _____

Circle the word that fits best:

hard muscles soft tough weak

Question 1 – Solution

Given:

north → south : strong → _____

The word that fits best is highlighted below:

hard muscles soft tough **weak**

The relationship is that the words are opposites (or antonyms). So, use a sentence such as:

The opposite of strong is _____. The word that fits best is “weak”.

Keep a score of how many you get right!

Analogical Reasoning Skill – Challenge for Experts

Question 1

Given:

water → ice : rain → _____

Circle the word that fits best:

cloud hail storm sunshine umbrella

Hint 1: Think about temperature.

Hint 2: Think about what can happen when the temperature drops below freezing.

Question 1 – Solution

Given:

water → ice : rain → _____

The word that fits best is highlighted below:

cloud **hail** storm sunshine umbrella

The relationship is that one is a frozen form of the other. So, use a sentence such as: Frozen rain can be in the form of _____. The word that fits best is “hail”.

Sequencing Skill – Sample

Sample 1

Given: 13 18 23 28 33

What is the pattern of how the numbers change?

Turn the page to check your answer.

Sample 1 – Pattern

Given: 13 18 23 28 33
+5 +5 +5 +5

Pattern: 5 is added to each number.

What are the next two numbers?

Turn the page to check your answer.

Sample 1 – Solution

Given: 13 18 23 28 33
+5 +5 +5 +5

Pattern: 5 is added to each number.

The next number is 38 because $33 + 5 = 38$.

The number after that is 43 because $38 + 5 = 43$.

Sequencing Skill – Activity

Question 1

Given: 2 3 5 8 12

The next two numbers in the series are

- a. 8 and 5 b. 12 and 16 c. 16 and 21 d. 17 and 23 e. 20 and 28

Hint 1:

Look for the pattern of how much each number increases.

It may help you to write down how each pair of numbers change.

Hint 2:

The amount of each increase is one more than the previous increase.

Hint 3:

The series of numbers is made by adding 1, then adding 2, then adding 3, and then adding 4. Continue this pattern by adding 5 to 12 and adding 6 after that.

Question 1 – Solution

Given: 2 3 5 8 12
+1 +2 +3 +4

The next two numbers in the series are

- a. 8 and 5 b. 12 and 16 c. 16 and 21 d. **17 and 23** e. 20 and 28

The numbers change by +1, then +2, then +3, and then +4.

The next changes are +5 and +6.

The next number is 17 because $12 + 5 = 17$.

The number after that is 23 because $17 + 6 = 23$.

Sequencing Skill – Summary

Summary

To find the next number of a series of numbers, you need to look for a pattern of how the entire series changes. The next numbers follow that pattern. Although it is uncommon, there may be more than one way to determine a pattern.

There are many possible patterns. Some of these include:

- Add regularly increasing amounts to get the next number.
This could be +4, then +5, then +6, and then +7.
- Subtract regularly decreasing amounts to get the next number.
One pattern could be -10, then -8, then -6, and then -4.
- Add different amounts to alternating numbers.
For example, +2, then +4, then +2, and then +4.
- Subtract different amounts from alternating numbers.
This could be -3, then -5, then -3, and then -5.
- Alternate between adding and subtracting.
One such pattern could be +4, then -2, then +4, and then -2.
- Alternate between multiplying and adding.
For example, $\times 3$, then +4, then $\times 3$, and then +4.

Sequencing Skill – Self-test

Question 1

Given: 5 7 11 17 25

The next two numbers in the series are

- a. 33 and 41 b. 33 and 43 c. 35 and 47 d. 42 and 67 e. 42 and 59

Question 1 – Solution

Given: 5 7 11 17 25
+2 +4 +6 +8

- a. 33 and 41 b. 33 and 43 c. **35 and 47** d. 42 and 67 e. 42 and 59

The next two numbers in the series are **35 and 47**.

The pattern is adding a number that increases by 2.

Sequencing Skill – Challenge for Experts

Question 1

Given: $-1/8$ $1/4$ $-1/2$ 1 -2

The next two numbers in the series are

- a. 3 and -4 b. $3\frac{1}{2}$ and $-5\frac{1}{2}$ c. $3\frac{1}{2}$ and $-6\frac{1}{2}$ d. 4 and -7 e. 4 and -8

Hint 1:

Look for the pattern of how each number changes.

It may help you to write down how each pair of numbers change.

Hint 2:

Each number is a multiplication of the previous.

Hint 3:

The series of numbers is made by multiplying by -2 . Continue this pattern by multiplying -2 by -2 and multiplying that result by -2 to get the next number.

Question 1 – Solution

Given: $-1/8$ $1/4$ $-1/2$ 1 -2
 $\quad\quad\quad x(-2)$ $x(-2)$ $x(-2)$ $x(-2)$

The next two numbers in the series are

- a. 3 and -4 b. $3\frac{1}{2}$ and $-5\frac{1}{2}$ c. $3\frac{1}{2}$ and $-6\frac{1}{2}$ d. 4 and -7 e. **4 and -8**

The numbers change by multiplying by -2 .

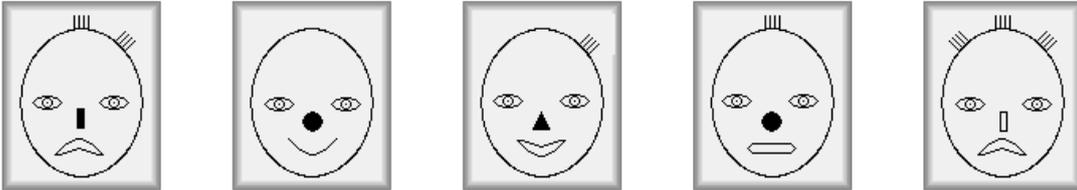
The next number is 4 because $-2 \times (-2) = 4$.

The number after that is -8 because $4 \times (-2) = -8$.

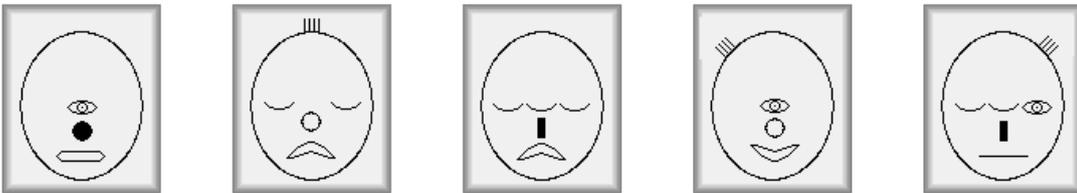
Patterning Skill – Sample

Sample 1

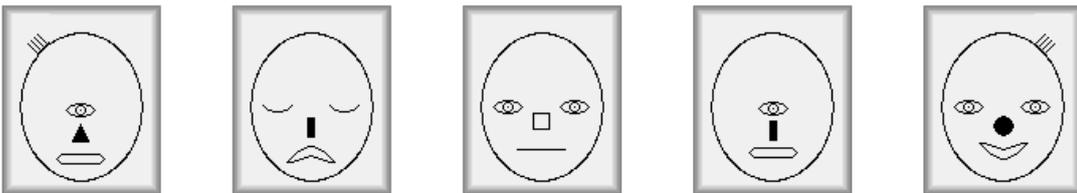
The following are chobs. Find their common characteristic(s).



The following are NOT chobs. Be sure they do NOT have those characteristics.

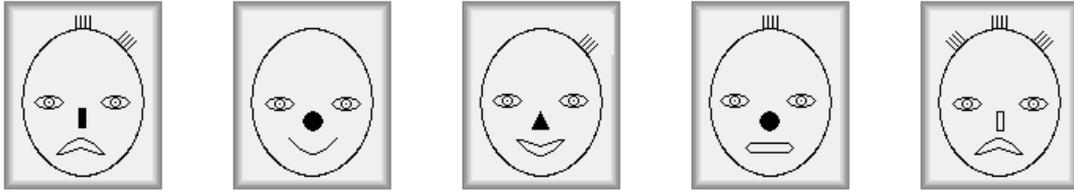


Of the following faces, which do you think is a chob? Turn the page to find out.

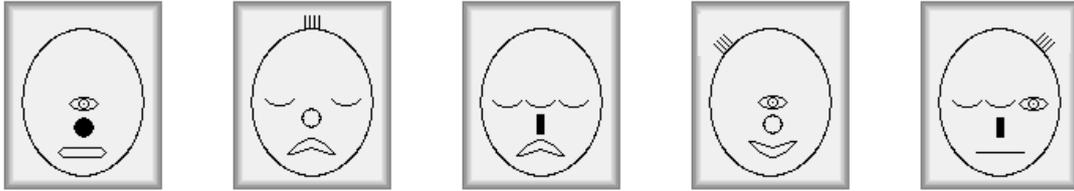


Sample 1 – Solution

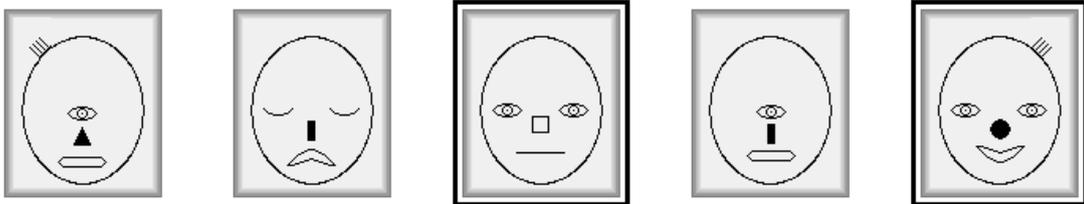
The following are chobs:



The following are NOT chobs:



The chobs are highlighted below:

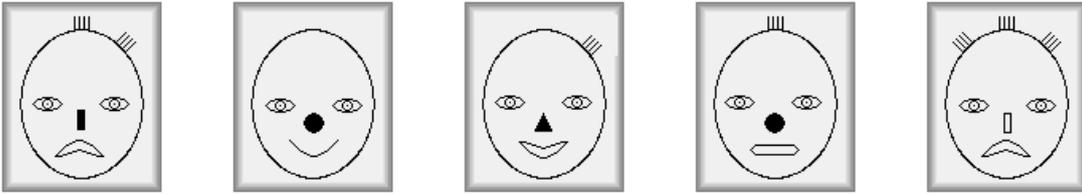


Think about why they are chobs. Look for the number of eyes, whether the eyes are open or not, the shape of a nose, whether the nose is solidly coloured or not, the shape of a mouth and whether it is open or closed, and whether there is hair and how much hair.

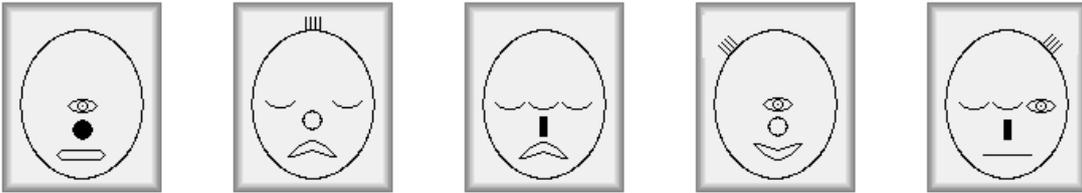
Turn the page to see if you are right.

Sample 1 – Explanation

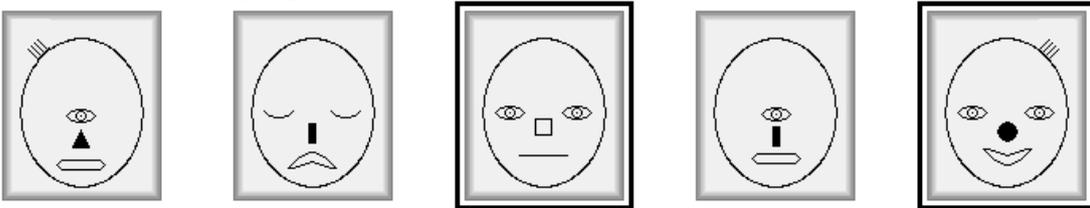
The following are chobs:



The following are NOT chobs:



The chobs are highlighted below:



Each chob has two open eyes.

Patterning Skill – Activity

Question 8

The following are belps:

A B P R

The following are NOT belps:

C F G O U

Circle each belp below:

D E H S Z

Hint 1: Look for TWO things common to all belps that non-belps do not have. Check shapes, pieces that form letters, symmetry, enclosed spaces, openings, direction of openings, and sound.

Hint 2: Find a shape common to each belp and determine whether belps have an enclosed space or an opening. Compare this to non-belps.

Hint 3: Check whether each belp has a straight or curved piece AND an enclosed space or opening. Compare this to non-belps. One of the letters in the last row is a belp.

Question 8 – Solution

The following are belps:

A B P R

The following are NOT belps:

C F G O U

The belp is highlighted below:

D E H S Z

Belps have an enclosed space AND a straight piece.

Patterning Skill – Summary

Summary

To find matching faces, letters, numbers, or fractions, you need to use logic and look for characteristics in the third series that match the first series but not the second series.

There are many possible common characteristics. A few characteristics are listed below:

In faces, look for the number of eyes, whether the eyes are open or not, the shape of a nose, whether the nose is solidly coloured or not, the shape of a mouth and whether it is open or closed, and whether there is hair and how much hair.

In letters, check the shapes within a letter, the pieces needed to form the letters, whether there is an enclosed space, whether the letter can be evenly split in half, whether the letter has an opening and to which direction the opening opens, and their sound.

In numbers, look for the presence and position of a specific digit, prime numbers, the sum of the digits, whether it can be evenly divided, multiplication, and whether it is odd or even.

In fractions, check for the same things as with numbers. However, do this in both the numerator and denominator.

Patterning Skill – Self-test

Question 6

The following are urgs:

$$\frac{3}{5} \quad \frac{12}{25} \quad \frac{18}{35} \quad \frac{27}{51} \quad \frac{30}{58}$$

The following are NOT urgs:

$$\frac{3}{14} \quad \frac{19}{25} \quad \frac{21}{30} \quad \frac{23}{25} \quad \frac{33}{60}$$

Circle each urg below:

$$\frac{2}{15} \quad \frac{15}{25} \quad \frac{21}{45} \quad \frac{36}{53} \quad \frac{45}{69}$$

Question 6 – Solution

The following are urgs:

$$\frac{3}{5} \quad \frac{12}{25} \quad \frac{18}{35} \quad \frac{27}{51} \quad \frac{30}{58}$$

The following are NOT urgs:

$$\frac{3}{14} \quad \frac{19}{25} \quad \frac{21}{30} \quad \frac{23}{25} \quad \frac{33}{60}$$

The urgs are highlighted below:

$$\frac{2}{15} \quad \boxed{\frac{15}{25}} \quad \boxed{\frac{21}{45}} \quad \boxed{\frac{36}{53}} \quad \frac{45}{69}$$

Urgs have numerators that are evenly divisible by 3 and denominators that contain a 5.

If you scored 4 or less out of 6:

You have completed this “Self-test”. You should repeat the “Samples” and “Activity” and then try this “Self-test” again.

If you scored 5 or 6:

You have successfully completed this logical thinking exercise! You are done but consider trying the “Challenge for Experts”.

Patterning Skill – Challenge for Experts

Question 6

The following are wubs:

208 406 604 1702 1900

The following are NOT wubs:

307 404 506 1432 1810

Circle each wub below:

204 408 802 1504 1800

Hint 1: Look for THREE things common to all wubs that non-wubs do not have.

Hint 2: One specific thing to look for is whether there is something common in any digit column.

Hint 3: In wubs, think about the sum of the digits, whether wubs are odd or even, AND whether there is something common in any digit column. Compare this to non-wubs.

Question 6 - Solution

The following are wubs:

208 406 604 1702 1900

The following are NOT wubs:

307 404 506 1432 1810

The wubs are highlighted below:

204 408 **802** **1504** 1800

Wubs are even numbers, have a “0” in the tens digit, AND all of the digits add up to 10.

Deductive Reasoning – Sample

Sample 1

	Eats meat	Vegetarian	Vegan
Alice			
Mad Hatter			
White Rabbit			

Alice, the Mad Hatter, and the White Rabbit have each made different choices about food. One eats meat, one is a vegetarian, while the other is a vegan. What choices have they made if:

- The White Rabbit is a vegan.
- The Mad Hatter is NOT a vegetarian.

Think about 2 things that can be filled in the matrix based on the given clues.

Turn the page when you have thought of 2 things.

Sample 1 – Given Clues

	Eats meat	Vegetarian	Vegan
Alice			
Mad Hatter		No	
White Rabbit			Yes

Alice, the Mad Hatter, and the White Rabbit have each made different choices about food. One eats meat, one is a vegetarian, while the other is a vegan. What choices have they made if:

- The White Rabbit is a vegan.
- The Mad Hatter is NOT a vegetarian.

Based on the given clues:

“Yes” can be placed in the White Rabbit-Vegan box.

“No” can be placed in the Mad Hatter-Vegetarian box.

Think about 4 things that can now be filled in the matrix.

Turn the page when you have thought of 4 things.

Sample 1 – Step 2

	Eats meat	Vegetarian	Vegan
Alice			No
Mad Hatter		No	No
White Rabbit	No	No	Yes

Since the White Rabbit is a vegan, he does NOT eat meat and is NOT a vegetarian. “No” can be placed in those boxes.

Since the White Rabbit is a vegan, Alice and the Mad Hatter are NOT vegans. “No” can be placed in those boxes.

Think about 2 things that can now be filled in the matrix.

Turn the page when you have thought of 2 things.

Sample 1 – Step 3

	Eats meat	Vegetarian	Vegan
Alice		Yes	No
Mad Hatter	Yes	No	No
White Rabbit	No	No	Yes

Since the Mad Hatter and the White Rabbit are NOT vegetarians, Alice must be a vegetarian. “Yes” can be placed in that box.

Since the Mad Hatter is NOT a vegetarian or a vegan, he must eat meat. “Yes” can be placed in that box.

Think about 1 thing that can now be filled in the matrix.

Turn the page when you have thought of 1 thing.

Sample 1 – Solution

	Eats meat	Vegetarian	Vegan
Alice	No	Yes	No
Mad Hatter	Yes	No	No
White Rabbit	No	No	Yes

Since Alice is a vegetarian, she does NOT eat meat. “No” can be placed in that box. This is also true because if the Mad Hatter eats meat then Alice does NOT eat meat.

The matrix is now complete and shows their choices about food.

Deductive Reasoning – Activity

Question 15

	2 pets	4 pets	6 pets	8 pets
Beckham				
Pele				
Ronaldo				
Zidane				

Beckham, Pele, Ronaldo, and Zidane each have a different number of pets. How many pets does each have if:

- Zidane has 4 more pets than Pele.
- Ronaldo has more pets than Pele.
- Beckham does NOT have the most or least number of pets.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Person	Number of Pets
Beckham	
Pele	
Ronaldo	
Zidane	

The next 2 pages have hints. The solution is after that.

Hint 1

	2 pets	4 pets	6 pets	8 pets
Beckham	No			No
Pele			No	No
Ronaldo	No			
Zidane	No	No		

Based on the given clues:

- Since Zidane has 4 more pets than Pele, Zidane does NOT have 2 or 4 pets.
- Since Zidane has 4 more pets than Pele, Pele does NOT have 6 or 8 pets.
- Since Ronaldo has more pets than Pele, Ronaldo does NOT have 2 pets.
- Since Beckham does NOT have the most or least number of pets, he does NOT have 2 or 8 pets.

Hint 2

	2 pets	4 pets	6 pets	8 pets
Beckham	No			No
Pele	Yes	No	No	No
Ronaldo	No			
Zidane	No	No		

Based on hint 1:

- Since Beckham, Ronaldo, and Zidane do NOT have 2 pets, Pele must have 2 pets.
- Since Pele has 2 pets, he does NOT have 4 pets.

From the information within the matrix, no further boxes can be filled in. When that happens, check the given clues to see if any new conclusions can be made.

The next page has more hints.

Hint 3

	2 pets	4 pets	6 pets	8 pets
Beckham	No		No	No
Pele	Yes	No	No	No
Ronaldo	No		No	
Zidane	No	No	Yes	No

Based on hint 2:

- Since Zidane has 4 more pets than Pele AND Pele has 2 pets, Zidane must have 6 pets.
- Since Zidane has 6 pets, he does NOT have 8 pets.
- Since Zidane has 6 pets, Beckham and Ronaldo do NOT have 6 pets.

Hint 4

	2 pets	4 pets	6 pets	8 pets
Beckham	No		No	No
Pele	Yes	No	No	No
Ronaldo	No		No	Yes
Zidane	No	No	Yes	No

Based on hint 3:

- Since Beckham, Pele, and Zidane do NOT have 8 pets, Ronaldo must have 8 pets.

The solution is on the next page.

Question 15 – Solution

	2 pets	4 pets	6 pets	8 pets
Beckham	No	Yes	No	No
Pele	Yes	No	No	No
Ronaldo	No	No	No	Yes
Zidane	No	No	Yes	No

Person	Number of Pets
Beckham	4
Pele	2
Ronaldo	8
Zidane	6

Deductive Reasoning – Summary

Summary

To solve “Clues” questions:

- Read and understand the question.
- Each question gives you initial clues. Based on each clue, place a “Yes”, for “Yes, it says so”, or “No”, for “No, it says it isn’t”, into the matrix.
- Based on what you have in the matrix, use logic to make one or more conclusions. An example of using logic is that wherever there is a “Yes”, every other box in that column and row must contain a “No”. As well, whenever all but one box of a column or row contains a “No”, the remaining box must be a “Yes”.
- Repeat this until the matrix is filled.
- The filled matrix contains the information needed to answer the questions.

Deductive Reasoning – Self-test

Question 7

	7:00	7:30	8:00	8:30
Batman				
Joker				
Riddler				
Robin				

Batman, Joker, Riddler, and Robin’s favourite television program each start at a different time. What time does each program start if:

- Joker’s favourite television program starts after 7:45.
- Riddler’s favourite television program starts before 7:45.
- Batman’s favourite television program does NOT start the latest.
- Robin’s favourite television program starts before 7:45.
- Robin’s favourite television program does NOT start at 7:00.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Answer:

Character	Program Start Time
Batman	
Joker	
Riddler	
Robin	

Question 7 – Solution

	7:00	7:30	8:00	8:30
Batman	No	No	Yes	No
Joker	No	No	No	Yes
Riddler	Yes	No	No	No
Robin	No	Yes	No	No

Character	Program Start Time
Batman	8:00
Joker	8:30
Riddler	7:00
Robin	7:30

Deductive Reasoning – Challenge for Experts

Question 2

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Bashful							
Doc							
Dopey							
Grumpy							
Happy							
Sleepy							
Sneezy							

The “Seven Dwarfs” each prefer a different day of the week. Assuming the week starts on Monday and ends on Sunday, what day does each prefer if:

- Bashful likes one of the days after Friday.
- Doc prefers a day in the week later than Dopey’s preferred day.
- Dopey prefers Wednesday.
- Happy prefers a day in the week earlier than the day Grumpy prefers.
- Sleepy prefers Sunday.
- Sneezy prefers the day before the day Bashful prefers.

Use logic to fill in the matrix with a “Yes” or “No” for any conclusion you can make.

Dwarf	Preferred Day
Bashful	
Doc	
Dopey	
Grumpy	
Happy	
Sleepy	
Sneezy	

Question 2 – Solution

New	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Bashful	No	No	No	No	No	Yes	No
Doc	No	No	No	Yes	No	No	No
Dopey	No	No	Yes	No	No	No	No
Grumpy	No	Yes	No	No	No	No	No
Happy	Yes	No	No	No	No	No	No
Sleepy	No	No	No	No	No	No	Yes
Sneezy	No	No	No	No	Yes	No	No

Dwarf	Preferred Day
Bashful	Saturday
Doc	Thursday
Dopey	Wednesday
Grumpy	Tuesday
Happy	Monday
Sleepy	Sunday
Sneezy	Friday