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Developing information literacy skills in elementary students using the web-based *Inquiry Strategies for the Information Society of the Twenty-First Century* (ISIS-21)

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Abstract

This study was undertaken to learn about the impact of using the web-based Inquiry Strategies for the Information Society of the Twenty-First Century (ISIS-21), software developed by the authors, to improve the information literacy (IL) skills of late elementary students (10-12 years). Using a series of multi-media and learning strategies design principles, ISIS-21 was designed to be used in late elementary classrooms given the gap in children's IL skills and the increasing importance for individuals to be critical consumers of information, particularly when using Internet-based environments. An exploratory, two-phase field trial was conducted in English schools in a central province of Canada. In both phases the research design was a one-group, pretest-posttest where data were collected from 150 students at the baseline and after the use of ISIS-21 for completion of an inquiry project. Teacher self-reports were also collected. The results were encouraging as we were able to establish the feasibility and importance of using ISIS-21 in classrooms to promote the development of IL skills in late elementary students.

Keywords

Canada; enquiry-based learning; information literacy; information technology; instructional design; primary education

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1. Introduction

The evolving needs of our information society and digital economy will have a tremendous impact on the nature of work in the coming decade, with complex technologies continuing to disrupt traditional careers, and young workers needing to thrive in a more uncertain 'gig economy' (De Stefano, 2015) and make sense of a more complex and uncertain information landscape permeated by bad information and fake news (Barclay, 2018; Burkhardt, 2017). Too many students lack the fundamental information literacy (IL) and inquiry skills such as identification, evaluation and synthesis necessary to support reading comprehension and writing, particularly within Internet-based environments (Leu et al., 2008; Saunders et al., 2017). The Organisation for Economic Co-Operation and Development (OECD) has adopted an updated definition of literacy to include how students locate and use information in different contexts. The OECD now notes in its Programme for International Student Assessment (PISA) that '[t]he ability to locate, access, understand and reflect on all kinds of information is essential if individuals are to be able to participate fully in our knowledge-based society' (OECD, 2019, p. 22). They are not the first to note that the society of the 21st century requires greater fluency with technology and information, and capability with information and communication technology (ICT) is essential (Binkley et al., 2012; Dede, 2010). Indeed this skillset harkens back to the original concept of 'information literacy' first described by Zurkowski (1974) as 'techniques and skills for utilising the wide range of information tools as well as primary sources in molding information solutions to their problems' (p. 6).

1.1 IL in the 21st Century

The nature of literacy has fundamentally changed since the widespread inception of the Internet (Coulombe et al., 2004; Knighton et al., 2010; Murray et al., 2009; New Literacies Research Team, 2007; Organisation for Economic Co-Operation and Development, 2004, 2007, 2010). Although traditional print-based texts are still a reliable source of information, today's youth prefers to turn to web resources (Asselin & Moayeri, 2010; Sormunen & Lehtio, 2011) in an increasingly mediated environment. Definitions of literacy as a singular concept have shifted to discussion of *literacies* – computer literacy, library literacy, media literacy, new media literacy and digital literacy (Bawden, 2001; Koltay, 2011). In their scope of the literature on such skills at the high school level, Stopar and Bartol (2019) note a shift from an emphasis on computer literacy toward IL and then to digital literacy post-2010, but all covering the same basic skills and competencies. As reading and writing habits move from paper to screen, literacy instruction is being modified to accommodate the new literacy strategies that are required in online, multimedia text formats (Leu et al., 2008). Key components for the development of new literacies for the 21st century include an emphasis on information and media literacy, critical thinking, problem solving and self-direction (American Association of School Librarians, 2018; Battelle for Kids, 2019; Conference Board of Canada, n.d.; Duncan & Varcoe, 2012; Fraillon et al., 2019; Grizzle et al., 2013; Koltay, 2011; Mittermeyer & Quirion, 2003; OECD, 2010; Partnership for 21st Century Skills, 2006).

According to the American Association of School Librarians (AASL) (2018), skilled readers should not only have decoding and comprehension skills in familiar contexts but also the ability to interpret and to develop new understandings in far-ranging learning contexts and situations. In this increasingly global world of information, students must be taught to seek and evaluate diverse perspectives, and to use technology as an important tool for learning, both now and in the future. Therefore, the skills that students need include how to:

- Develop and refine a range of questions to frame their inquiry for new understanding.
- Find, evaluate and select appropriate resources on the basis of accuracy, reliability, validity and relevancy.
- Make sense of information gathered from diverse sources by identifying main and supporting ideas, misconceptions, conflicting information and points of view or bias.
- Maintain a critical stance by questioning the validity and accuracy of all information.
- Monitor gathered information to assess gaps and weaknesses.

As technology and the Internet are pervasive parts of everyday life, and the information landscape becomes ever more complex (participatory media, quality and reliability of information), the importance of developing these skills is critical.

1.1.1 State of IL instruction

Various national and international associations have recognised the critical importance of teaching IL skills (Association of College and Research Libraries, 2016; American Association of School Librarians, 2018; Canadian Library Association, 2014; Conference Board of Canada, nd; International Society for Technology in Education, 2017; Wilson et al., 2011). Yet still today, few school curricula specifically address the teaching of the skills required to be successful in an online information economy (Gates, 2007; Yevelson-Shorsher & Bronstein, 2018). In many cases, teachers lack basic IL skills themselves as such skills are excluded from North American teacher education programs (Canadian Library Association, 2014), which results in teachers not explicitly teaching these skills at all (Henry, 2005; Ladbrook & Probert, 2011; Probert 2009). Others advocate that teachers would be more likely to teach IL skills if their teaching strategies shifted from a teacher-directed to a learner-centred approach (Wilson et al, 2011). Severe cutbacks in school library staff and teacher-librarian programs have also contributed to a gap in the teaching of IL (Haycock, 2003; Whitehead & Quinlan, 2002) or have resulted in a lack of institutional backing so that students are unaware of available resources (Yevelson-Shorsher & Bronstein, 2018). This problem is amplified and exacerbated when students complete homework, as parents also lack IL skills to help their children with effective research and information evaluation strategies (Lee & Chae, 2012). More than any other school topic, adults are seen to need as much help as youngsters learning IL skills both for themselves and to support the learning of students (Kong & Li, 2009).

1.1.2 State of information skills

For their 2009 PISA assessment, the OECD updated their definition of literacy to include a focus on digital literacy and reading digital texts, and reported results for both the traditional reading scales and the new digital reading scales. Not all countries participated in the data collection for the new scales, though it was found that across all participating countries, digital reading performance is similar to the level of print reading (OECD, 2010). Relative to other developed nations, the academic performance of students in the United States was modest (Provasnik et al., 2009). Countries like Korea, New Zealand and Australia showed a stronger performance in the digital tasks than the print-based reading tasks in the PISA (OECD, 2010) report, but other countries showed that students are struggling in this new digital environment - in Austria, Chile, Hungary and Poland, more than a quarter of students fail to achieve Level 2 proficiency, and in Columbia it was found that nearly 70% of students fail to make this threshold. While there is still a marked difference in the success rate of girls, the difference is less marked in the digital

domain than for print (OECD, 2010). The PISA 2018 report (Schleicher, 2019) continued to closely evaluate students' ability to work with texts and information in digital contexts, noting that 'fewer than 1 in 10 students in OECD countries was able to distinguish between fact and opinion, based on implicit cues pertaining to the content or source of the information' and that 'that improvements in education have not kept up with these rising demands' (p. 14). There was only a marginal increase of 2% (from 7% to 9%) among 15-year-olds performing at the highest level (only 1 in 7 Canadian students were able to do so).
At the secondary education level, Julien and Barker (2009) surveyed high school biology students and found that their IL skills were underdeveloped, noting that IL skills are not a part of provincial exams (in Alberta, Canada) and are therefore perhaps not seen as a priority by teachers. Researchers have often considered IL skills as necessary precursors to success in university, but while students may recognise the importance, they are not always adequately trained or informed of available resources (Smith et al., 2013). For example, a large scale survey of incoming undergraduate students across the Canadian province of Quebec showed that students struggled with many key IL competenies, with correct answers falling below or well below 50% (Mittermeyer, 2005). Another survey (Beheshti et al., 2018) comparing the IL skills of first year Canadian vs international undergraduate students, found that in both groups the majority of students used Google as their main source when conducting research.

There is the need for substantially more data on the current state of children's IL skills. Recognising this gap and the significant increase in the use of ICT resources - both within the K-12 classroom and outside of the classroom, OECD (2019b) has recently developed a framework with the intent to provide a more systematic approach for measuring the impact of ICTs on teaching and learning. This new approach represents a shift from measuring digital reading literacy, which combines the assessment of subject-specific achievement with ICT use. The framework will be used in the PISA 2021 data collection run and results will reveal the extent to which ICTs are used by secondary students, and how this use influences the development of IL-related competences, incuding such constructs as student engagement, motivation, task performance and meta-cognition. The Progress in International Reading Literacy Study (ePIRLS Online Reading, 2016) assessing how well children read after four years of compulsory elementary schooling has also made a first move in this direction. An extension to the PIRLS assessment: ePIRLS has been created to measure grade-four students' achievement in online reading for informational purposes.

1.1.3 IL and self-regulated learning

Research points to the need for a systematic approach to teaching the fundamental processes related to IL, including; the articulation of a query, the understanding, selection and use of appropriate retrieval tools, the proper evaluation of web-based sources and the ability to effectively use the information for the generation of new knowledge (Adams, 2014; Chen et al., 2017). Weiner (2011) highlights the conceptual complementarity of IL and critical inquiry and emphasises that effective instruction provides tools and techniques in the processing and utilisation of knowledge and integrates the interpretative strategies and skills of critical thinking. Linked to these strategies is the process of self-regulated learning (Hadwin et al., 2018; Zimmerman & Schunk, 2011). Self-regulated learners are individuals who are metacognitively, motivationally and behaviorally active participants in their own learning (Zimmerman, 2000). Academic self-regulation involves the strategic application and adaptation of learners' cognitive and metacognitive thought processes in influencing their own behaviors while tackling academic

tasks, taking into account their emotions as well as motivational states within a specific learning context or environment (Pintrich, 2003). The ability to self-regulate is important for students to develop and refine especially for the purpose of critical inquiry. Following their meta-analysis, Dent and Koenka (2016) concluded that self-regulated learning (SRL) has a clear impact on achievement across grades, by providing students with cognitive strategies and processes that help them learn.

A number of researchers have noted a strong link between SRL and the concept of IL (Kurbanoglu, 2003; Ross et al., 2016; Wolf, 2007). Kiliç-Çakmak (2010) explored this nexus and found a number of self-regulation strategies that particularly influenced successful implementation of key IL skills, the most important being use of metacognitive strategies. Other successful strategies included effort management (persisting through tasks that students perceive as boring, as well as ignoring distractions), elaboration (taking notes and making comparisons between sources of information), and critical thinking. Muthupoltotage and Gardner (2018) also found strong relationships between digital literacy and SRL skills, and that SRL had a significant positive effect on various IL skills and vice versa. As a result, recently developed IL standards (AASL, 2018; ACRL, 2016; Battelle for Kids, 2019; CLA, 2014; ISTE, 2017; UNESCO (see Grizzle et al., 2013)) have incorporated the development of self-regulated learning's set of skills, attitudes, behaviors, thus leading to lifelong learners.

1.1.4 Interventions for IL

In the decades since Zurkowski (1974) first proposed the concept of IL, librarians and researchers across the globe have worked towards designing relevant curricula and frameworks, and effective tools and strategies to teach these important skills. Researchers have looked at understanding the information seeking behaviour of young children (Large et al., 2008; von Loh & Henkel, 2014) and implementing IL instruction as early as kindergarten (pre-school) (Tecce DeCarlo et al., 2018). Interventions have been developed for use in elementary (Nesset, 2015; Rodney-Wellington, 2014) and middle school (Chu et al., 2011; Foo et al., 2017). Baji et al. (2018) used the Big6 model in an IL intervention, first developed by Eisenberg and Berkowitz (1990), which stresses six main elements: Task Definition; Information Seeking Strategies; Location and Access; Use of Information; Synthesis; and Evaluation. Their results were positive, with the experimental group demonstrating a significantly better IL achievement. Chen (2011) applied the Super3 model (Plan, Do, Review) of IL instruction with first grade science classes and found a significant improvement in skills. In his study, Newell (2010) looked at the use of simulation technology to impart general IL instruction with middle school students, which proved successful in increasing students' IL abilities to formulate research questions, identify information sources and judge the accuracy of the information. At the secondary level, Wilson et al. (2017) used game-based learning to teach IL skills to high school students and found the games to be a successful method for imparting information skills. Chen and Ma (2012) employed the Big6 model in a high school context to deliver science instruction to grade 7 classrooms, and found that the experimental group exhibited stronger problem-solving and comprehension skills. For their part, Argelagós and Pifarré (2012) targeted what they term Information Problem Solving (IPS) skills, in a two-year intervention with seventh and eighth grade students that used web-based instruction based around a WebQuest approach with emphasis placed on embedded instruction and scaffolds. After treatment, students were found to be more efficient searchers (including better use of search terms) and therefore able to spend more time on higher level skills such as analysing and processing the retrieved information.

1.2 ISIS-21 – A Web-based platform for IL instruction

To address the critical importance of developing IL skills in young learners, we developed interactive web-based software entitled ISIS-21 (a more recent version is called IS-21). We first describe the software and then explain the thinking behind its design.

ISIS-21 is a bilingual (English and French) web-based, interactive learning platform designed to teach middle school students (grades 5–8) IL skills within the context of an inquiry. Students develop their IL skills as they work on researching a substantial, meaningful question. The tool is divided into three major sections: *Planning, Searching,* and *Using Information*. In each section, there are interactive steps to complete, each designed to develop a specific IL sub-skill, with embedded help tools to insure students develop IL skills and a deep understanding of the inquiry process. See Figure 1 for a map of the ISIS-21 inquiry process.

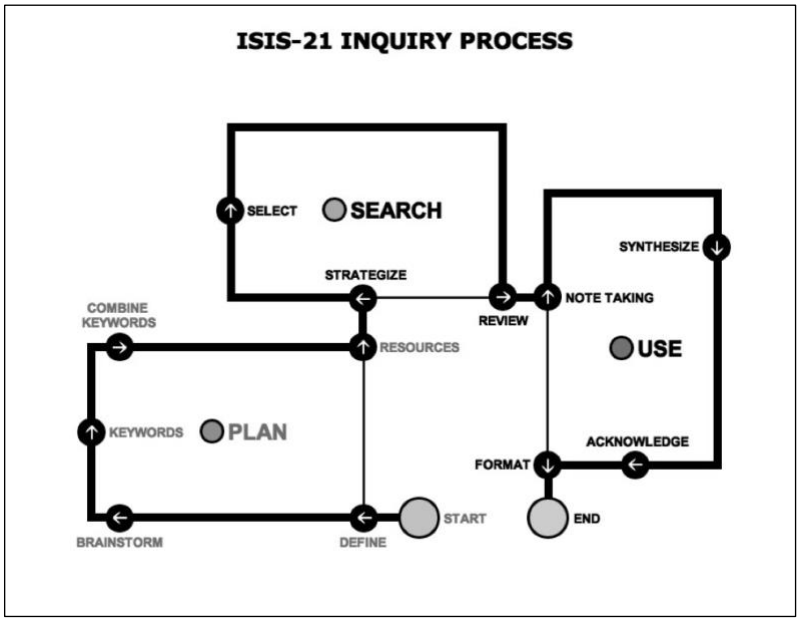

Figure 1: ISIS-21 map of the inquiry process

ISIS-21 went through four iterations of design and development each driven by the ADDIE instructional systems design model with its five phases of analysis, design, development, implementation and evaluation. The ongoing evaluation enabled each phase to feed meaningfully into a subsequent phase whereas the feedback provided by 294 pilot users of ISIS-21 over the years informed the following cycles of the design and development process.

1.2.1 Specific features & functionalities

ISIS-21 is a constructivist, inquiry-based learning environment designed to support a diversity of students' needs as they conduct their inquiry, and to provide enough flexibility such that it may be used in any content area. The three phases of *Planning, Searching* and *Using Information* are divided into twelve steps. Students are initially expected to work through each of the steps within a phase in a linear fashion; however, they may proceed to the next step without having completed a step. At any time, they may re-visit a step to modify work that has been done or to finish the step. See Appendix 1 for illustrations and examples of the ISIS-21 process.

At the *Planning* phase students identify their information need, the key ideas at the root of their subject, and determine the best resources to use to meet their needs. This phase consists of six steps. The first step, *Start*, is based on the teacher framing the context of the task and making sure that the student has comprehended the assigned task. Specifically, students are asked to write out an assigned task and describe in their own words their understanding of this task and how they can complete it. The other five steps are intended to help students identify their needs by formulating big and specific research (little) questions, pulling key concepts out from each and mapping out a strategy on how to find the best information given their needs. Based on the information provided, an Action Plan is generated to guide a student throughout the three steps of the *Searching* phase. They follow these steps by exploring different retrieval resources, evaluating their Action Plan, scanning and organising the sources they are finding, evaluating the appropriateness of those sources and finally selecting sources based on their quality and relevance. While progressing though the four steps of the *Using Information* phase, students learn how to take notes on the sources they determined were appropriate to use. Then they synthesise all of the information that they found from their various sources and organise that information into a cohesive outline that may be used to guide the final product that is produced to answer their big question. Students learn to treat the information they find in an ethical manner by quoting or paraphrasing and documenting the bibliographic information in the required citation style. Finally, they present their finished product.

1.2.2 Link to ePEARL

For many students, the ability to self-regulate enhances their learning (Azevedo, 2008; Azevedo & Witherspoon, 2009). Therefore, ISIS-21 is linked with another multimedia software tool, ePEARL also developed by the authors and shown to encourage students to cyclically self-regulate (Abrami, Bures et al., 2013; Abrami, Venkatesh et al., 2013; Abrami et al., 2008; Meyer et al., 2010). Students can move seamlessly between the ISIS-21 and ePEARL platforms to set goals, plan strategies, develop versions of their inquiries and reflect on the inquiry process as well as give and receive feedback from others. As ISIS-21 reports are automatically linked to an ePEARL task, teachers and peers are able to provide feedback as the process unfolds. By linking the tools, rather than combining them, students have increased flexibility and control over their learning environment and individualised feedback can help transfer skills to other learning contexts more easily. See Appendix 2 for illustrations of this link to ePEARL.

1.2.3 Student support

To assist students in their learning of IL skills, multiple points of support have been embedded into ISIS-21. The software offers quick snapshots of the purpose of each step and the actions to be taken as well as the tips to complete them. Furthermore, each ISIS-21 feature has in-context help geared to students by providing conceptual, pedagogical and technical support to them. Each help includes the following sections: *Tell Me More* (explanation), *Example*, *How Can I Do This*? (pedagogical support), and *What Do I Do in* ISIS-21? (technical support). Some screens also contain an embedded student support video that models the process. Accessible at any stage of the ISIS-21, an online interactive activity has been designed to provide further pedagogical support on each step of the inquiry process. Teachers may choose to use the game as an introductory activity to the topic of the inquiry process. Students may see the value of revisiting the game as their inquiry unfolds for help with a particular step. Lastly, the ISIS-21 report feature may be used by both students and teachers to provide a snapshot of work that has been completed as the inquiry process unfolds.

1.2.4 ISIS-21 instructional design

Mayer's (2009) cognitive theory of multimedia learning guided the instructional design for ISIS-21 as did other theories explaining successful cognitive skill acquisition. First, when faced with a learning task, there needs to be an authentic or genuine purpose in performing the task at the time of learning because that maximises the likelihood that the mental state of the learner will closely match the mental state required when putting that learning into action (with the prompts of the ISIS-21 software). If the learner's sense of purpose remains contrived, learning will not be as 'transfer appropriate' as it should be. Therefore, ISIS-21 is designed to be used for term-long projects where students explore a complex question that is personally meaningful and important under the direction of the classroom teacher, thereby also enhancing their intrinsic interest and self-efficacy (Pintrich, 2003). By specifying a 'big question' (Bransford et al., 2000) to explore and linking it to ePEARL, students are able to set personal learning goals to pursue and strategies for achieving those goals.

Second, in both ISIS-21 and ePEARL the key elements of inquiry and self-regulation are scaffolded (Saye & Brush, 2002; Vygotsky, 1987; Wood et al., 1976). The main elements of both the inquiry process and the self-regulation process are visibly structured in the tool, but sub-elements are also available to the user as needed, allowing both guidance from the tool and choice by the student.

Third and related to scaffolding, is embedded multimedia (Chambers et al. 2008; Chambers, Abrami et al., 2011; Chambers, Slavin et al., 2011) and just-in-time support (Abrami et al. 2010; Abrami, Venkatesh et al., 2013; Meyer et al., 2010) presented in learner paced-segments which model (Bandura, 1986) and explain key processes. These brief vignettes along with written explanations and suggestions, found in the embedded help will encourage the understanding of the key processes of inquiry.

Fourth, to maximise student self-efficacy beliefs, ISIS-21 was designed to be easy and intuitive to use, requiring minimal technical training and support, and including regular self-monitoring.

Finally, both an instructional game and inquiry map embedded in ISIS-21 serve as advance organisers and concept maps. Nesbit and Adescope (2006) summarise evidence that such techniques can facilitate student comprehension and will be used, in this case, to clarify the stages of inquiry.

1.3 Objectives of this study

The intent of this study was to learn about the feasibility and potential impact of using the structured environment offered by ISIS-21 on the development of older elementary school students' IL skills within the context of an inquiry. We expected that the impact of this ISIS-21 intervention, when used in a term long project or longer, would be to produce gains in IL, self-regulated learning and literacy skills. Specifically, we explored the following research questions:

- How and to what extent does the quality and quantity of use of ISIS-21 impact the development of IL skills in older-elementary students?
- To what extent does the use of ISIS-21 on the development of IL skills vary by grade level?

- Does the use of ISIS-21 improve the development of self-regulated learning skills in older-elementary students?
- Does the use of ISIS-21 improve the development of literacy skills in older-elementary students?
- Does the length of a teacher's experience of using ISIS-21 impact the development of IL skills?
- What are student and teacher perceptions related to the use of ISIS-21 and the development of their IL skills?

2. Method

2.1 Study design (Phases 1 & 2)

This paper reports the results of an exploratory, two-phase field trial conducted in English schools located in urban, suburban and rural areas in a central province of Canada. The first phase took place in the spring of 2014 and the second phase followed in the fall (autumn) of 2015. In both phases the research design was a one-group, pretest-posttest where the student data were collected at the baseline and after intervention. Teacher self-reports were collected alongside the students' post-tests. Informed consent was obtained from teachers and students' parents following Canada's Tri-Council Policy on the ethical treatment of research participants (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council, 2018) Having chosen to use ISIS-21 for an inquiry project in their subject, the participating teachers followed the provincial curriculum requirements and were at liberty to decide on the theme and nature of the project.

2.1.1 Study sample

The participants in phase 1 of the field trial were five teachers and their 182 students in nine classes. As table 1 shows, the majority of these were late elementary students (N=150), whereas a handful were early elementary (N=24) and early secondary (N=8). Because the measure we used was not appropriate for grade 3 students, pre- and post-test data were not collected in these classes. Further reduction in the sample size occurred after the parents of three students did not give their permission to use their children's data and four students did not complete one of the tests. Therefore, the data of 150 students were analysed. In phase 2, there was one continuing teacher with her 39 new students from two grade 5 classes. After excluding two students whose parents did not give permission for the data to be collected and two students who missed one testing, the sample of 35 was left for the analyses.

Table 1: Number of students/classes in each phase of ISIS-21 study

	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7-8 (split)	Total
Phase 1	24/1	47/2	70/3	33/2	8/1	182/9
Phase 2			39/2			39/2

2.1.2 Intervention. Two phases

At the start of phase 1 in the winter of 2014, six teachers received a one-day training in ISIS-21 and the IL-related skills developed within the tool. Five teachers were trained face-to-face whereas one was trained remotely via the ZenLive virtual classroom. At the training the

participants were provided with access to the collection of ISIS-21 teacher resources including lesson plans and thematic units specifically centred on the teaching of IL sub-skills. Grade-levelled thematic units were offered on Recycling, Natural Disasters and Advertising. Additionally, teachers were provided with a set of job aids and classroom resources such as visual organisers, an evaluation rubric, a poster outlining criteria for the evaluation of sources, student-centred videos of the key components of the inquiry process and videos of completed ISIS-21 projects. The decision to use these materials was left to the teachers' discretion. Five teachers used the recommended thematic units to integrate ISIS-21, whereas one teacher selected the subject related to the book her students were reading in their English language Arts class. The research team provided on-going classroom support to the teachers by modelling instruction, team-teaching and helping students in their use of ISIS-21. A swap and share workshop was offered to the participating teachers at the end of phase 1 as a forum for sharing their experience completing the ISIS-21 projects.

Since the teacher who participated in phase 2 of the project was a continuing teacher from phase 1, no formal training was offered for phase 2. In this phase, the provision of support by the researchers was minimal and limited to the occasional support of students as they worked on ISIS-21.

In both phases students were required to complete the twelve ISIS-21 steps as their inquiry unfolded. This involved defining a big question, breaking this question into researchable little questions and extracting key concepts from each, designing effective search strategies, collecting and evaluating relevant and credible sources, taking notes on what they had retrieved and ultimately producing a product that creatively illustrated their answer to the big question. Over 12 or 13 weeks students worked in small teams of three or four on their inquiry project. The weekly time allotted to the project was split between teaching the IL-related concepts for each ISIS-21 step, having students work in small groups to discuss their course of action and having each student complete the various steps with ISIS-21. Because it was difficult for the teachers to trouble shoot at a distance, ISIS-21 was used only in class, and no home use of the tool was expected from students. The time each student spent using ISIS-21 was tracked within the software. Although the time when a student was inactive while using ISIS-21 is counted in, we considered this statistic as a valid estimate of a student exposure to ISIS-21 and IL–related instruction because the students used ISIS-21 mainly during class time. The data summarised in Table 2 suggest that the average time a student used ISIS-21 varies primarily as a factor of grade level and phase of the study, with grade 5 students spending the most time in ISIS-21. Moreover, grade 5 participants in phase 2 on average spent 100 minutes more than their peers from phase 1.

Table 2: Average time a student used ISIS-21

Phase 1	Grade	Average time (min)	Min	Max

	7-8 (split)	90	52	123
	6	260	260	263
	5	325	279	350
	4	151	145	157
Phase 2	5	423	414	431

To access to the technology, laptops were loaned to the ISIS-21 classrooms. These were used as a supplement to their classroom computers and school computer labs. The teachers also used interactive electronic boards to demonstrate the features within each of the ISIS-21 steps to their students.

The format of the products that resulted from the inquiry projects varied according to the thematic unit that was used and included: student presentations on the environmental impact of implementing a recycling program in the school, a mock meeting between an advertising executive and a potential client that included a multimedia presentation of a recommended advertisement, a newscast announcing the impact of a natural disaster and the design of a webpage.

2.2 Instrumentation

2.2.1 Measures of IL skills

A modified version of the Tool for Real-Time Assessment of Information Literacy Skills (TRAILS-9) (Kent State University Libraries, n.d.; Owen, 2010) was used in all phases of the field trial to measure the change in the development of students' IL skills. Modifications that were made to the original assessment with the permission of the TRAILS team included: (a) transferring the online test to paper medium; (b) reducing the number of items; (c) reducing the cultural bias of the items and adapting them to Canadian context and (d) equalising the number of items to the number of steps in the ISIS-21 three phases. As a result, the modified version included 23 items related to *Plan* (11 items), *Search* (6 items) and *Use* (6 items). Out of these, 14 were the original items.

An updated version of Online Reading Comprehension Assessment Elementary-Revised (ORCA) (Kingsley, Cassidy & Tancock, 2015) was used at the post-test in phase 2 of the trial as a complimentary measure of IL . The four informational tasks built on the age appropriate Internet content required students to complete a mini inquiry project by applying their skills of (1) asking questions, (2) locating information, (3) critically evaluating web information, (4) synthesising of information from multiple websites and (5) effectively communicating information to others. The four tasks were split in two forms and posted online. Forms alternated between students and each student was provided with up to 60 minutes to complete the form. The ORCA Elementary-Revised rubric was used to evaluate students' responses.

2.2.2 Extent of use of ISIS-21

The ISIS-21 report generated by the software documented the students' progress in completing each of the ISIS-21 phases.

2.2.3 Measures of self-regulated learning skills

To measure students' perceptions of their use of self-regulated learning strategies, Student Learning Strategies Questionnaire (SLSQ forms A and B*,* available at https://www.concordia.ca/research/learning-performance/knowledge-transfer/instruments.html) was used in phase 2 of the project. An update to the original Student Learning Strategies Questionnaire (SLSQ) (Abrami, Venkatesh et al., 2013), version 2 inquired about students' ability to set learning goals, observe and correct their performance and reflect on the learning outcome as well as students' perceptions of self-efficacy, self-determination and self-worth.

2.2.4 Measures of literacy skills

The fourth edition of Canadian Achievement Test (CAT-4) (Canadian Test Centre, 2008) a standardised achievement test developed in the Canadian context was used as a measure reading skills. One school board administered the test and therefore the scores were available for 57 grade 5 students taught by one teacher. Upon request the school board provided the data file of CAT-4 scale scores prepared by the Canadian Test Centre. In our analysis we used Total Reading scale scores of CAT-4.

2.2.5 Measures of teachers' experiences

A Teacher Exit Interview Protocol (Concordia University, 2019) was used for teacher exit interviews. This semi-structured interview protocol was designed to explore the reasons for teachers' varying degrees and types of ISIS-21 implementation including their expectations, access to technology, support from administration and tech personnel, familiarity with research process pedagogy, knowledge and time management issues.

2.2.6 Measures on perceptions of ISIS-21

An ISIS-21 survey (student and teacher*)* elicited reports about the teachers' and students' experience using ISIS-21 for an inquiry project. The items on the student survey pertained to their time spent weekly in ISIS-21, their perception of ISIS-21 (easiness, clarity of instructions, prompts and help screens); their perception of the time and effort it took to complete the ISIS-21 steps, and their willingness to use ISIS-21 in the future. A set of open-ended questions asked the students about any technical problems they experienced, the parts of ISIS-21 that were easy to complete and that they liked the most or the least, as well as the IL-related skills they would use the next time they conducted an inquiry. The teacher survey echoed that of the students by asking for their perception of their students' experiences using ISIS-21 and the development of their IL-related skills. In addition, the survey elicited teacher responses on the challenges of classroom implementation, as well as suggestions for additional support materials teachers would need so as to better integrate the use of ISIS-21 when assigning future inquiry projects.

2.3 Analyses

All student and teacher data were entered in separate data files using SPSS 22 for Mac OS X, and then verified for accuracy and screened. The screening procedures revealed no marked kurtosis or skew in the data nor univariate outliers suggesting that the data were normally distributed. Therefore, the data was analysed using a number of parametric statistical tests.

First, to detect changes in students' leaning overtime, paired sample t-tests were run on the pre- and post-test scores of IL (TRAILS, phases 1 and 2), and self-regulation (SLSQ, phase 2).

Then, to examine if the grade level accounted for the variation in phase 1 IL scores as measured by TRAILS, the standard Multiple Linear Regression analysis was applied.

Further, correlation analyses were used to test for the association between the measures (a) of IL skills, TRAILS and ORCA as well as TRAILS and ISIS-21 progress (reflected in the ISIS-21 reports); (b) IL (TRAILS) and self-regulation skills (SLSQ); as well as (c) IL skills (TRAILS) and reading achievement scores (CAT-4). To assess student progress in ISIS-21, a set of 22 ISIS-21 reports were randomly selected from students in grades 4, 5 and 6 who had been split in low, average and high groups according to the students' gains in IL measured by TRAILS. Three instructors of IL then independently evaluated each of the 22 reports using the 4-point rubric designed to assess the outcomes of the IL process. Their ratings were then compared using intra-class correlation coefficient yielding moderate inter-rater reliability of 0.63 (CI = 95%).

Finally, to examine if the length of teacher experience using ISIS-21 has impact on IL, an independent two-sample t-test was performed on the TRAILS gain scores of grade 5 students taught by the same teacher in phases 1 and 2.

In addition, descriptive statistics were used to generated summaries of the student and teacher self-reports of their ISIS-21 experiences.

3. Results

3.1 Student outcomes

The results from Phases 1 and 2 of the ISIS-21 project are reported consecutively in this section to answer the question *How and to what extent does the quality and quantity of use of* ISIS-21 *impact the development of IL skills in older-elementary students*? Table 3 shows that in phase 1 after the term-long ISIS-21 inquiry project, students significantly improved their IL skills pertaining to planning their inquiry, searching and using information as measured by TRAILS assessment. On the three TRAILS subscales, the average increase ranged from 10 to almost 15 percent points. Specifically, at the post-test, an average student was able to complete 70% of the 11 items on planning, 59% of the 6 items on information searching and 75% of the 6 items on information using.

Table 3: Phase 1 TRAILS descriptive and paired t statistics (N=150)

	Pre-test	Post-test	t-dependent

	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	sign.
Planning (11 items)	6.57	2.00	1.00	10.00	7.67	1.98	0.00	11.00	9.95***
Searching (6 items)	2.63	1.27	0.00	6.00	3.53	1.32	0.00	6.00	6.1***
Using (6 items)	3.79	1.41	0.00	6.00	4.53	1.32	0.00	6.00	7.1***
Total (23 items)	13.00	3.68	4.00	21.00	15.73	3.90	1.00	23.00	6.62***

*** p<.001

To test if the TRAILS gain scores change as a function of grade-level of students who completed the ISIS-21 project, 4 multiple regression models were run where gains on TRAILS scores were the criterion variables. The results show that the grade level did not significantly account for the overall variation of IL skills as measured by TRAILS (R^2 ranged between .001 and .036). However, students in the younger grades showed significantly higher gains on the subscale of the *Planning* process (ß= .54; p< .05). Younger students also demonstrated higher but statistically non-significant gains on the *Using* information subscale of TRAILS. Conversely, gains in *Searching* for information were larger for the students in senior grades.

By and large, as shown in Table 4, TRAILS results obtained from two classes of grade 5 students in phase 2 follow the pattern revealed in the phase 1 data. In particular, the students' gains were significant for overall and specific IL skills, such as *Planning, Searching* and *Using* information. Similar to the phase 1 findings, the highest gains were for *Planning* and were followed by improvements in the *Searching* and *Using* phases.

Table 4: Phase 2 TRAILS descriptive and paired t statistics (N=35)

	Pre-test				Post-test				t-dependent sign.
	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	
Planning (11 items)	6.83	2.04	2.00	10.00	8.62	1.78	4.00	11.00	6.04***
Searching (6 items)	2.71	1.01	1.00	5.00	3.65	1.23	0.00	6.00	4.07***
Using (6 items)	3.77	1.09	1.00	6.00	4.54	1.09	2.00	6.00	4.69***
Total (23 items)	13.31	3.68	8.00	18.00	16.82	3.02	7.00	22.00	9.28***

*** p< .001

To complement the TRAILS scores of IL skills, in the Phase 2 post-test we used an additional measure of IL, ORCA. As expected ORCA and TRAILS post-tests scores were positively and significantly although modestly associated (Pearson r= .39, p< .05). On average, students' success rate in ORCA's mini research assignments ranged from 86% to 22.2%. It is important to note that although a dominant majority of the students provided answers to the ORCA questions, their answers were either too general or only partially correct. The most challenging aspects of ORCA for the students were to offer logical reasoning based on what they learned

from the information found, as well as to use strategies to triangulate information. As a result, only a handful of students (37%) successfully completed 60% and more of the ORCA tasks.

We also explored if an individual student's progress through the ISIS-21 phases as reflected in their ISIS-21 reports generated by the tool, associated with the TRAILS post-test scores. The analysis yielded an overall positive statistically significant correlation between the two measures (Cronbach's alpha = .48, p< .05). Correlations between the subscales of TRAILS and those of the ISIS-21 reports were positive and varied from .13 (p > .05) to .73 (p< .001). Statistically significant associations were observed between three TRAILS subscales of *Planning, Searching* and *Using information* and the ISIS-21 report scores of selecting sources with Cronbach alphas of .60, p<.01; .61, p<.01 and .54, p<.01 respectively. The ISIS-21 report scores of note-taking and synthesising information positively associated with TRAILS searching with correlation values of .58, p<.01 and .73, p<.000.

Another significant outcome of completing an ISIS-21 project in phase 2 are statistically significant gains in the students' self-regulation skills (t= 3.87, p< 0.001) measured with the SLSQ. This improvement particularly pertains to the following aspects: reflection (t= 9.79, p< 0.001), task value (t= 2.94, p< 0.01) and self-efficacy (t= 2.06, p< 0.05). With the exception of negative changes in self-determination and monitoring, the increase in students' self-reported scores on planning, and perceptions on self-worth and multimedia interaction were also positive although not statistically significant. We found no statistically significant association between students' self-reported self-regulation and TRAILS scores.

To answer the question, *Does the use of ISIS-21 improve the development of IL in older-elementary students?* on permission granted by the school board, we explored a potential association between the TRAILS scores of grade 5 students and their reading achievement measured with the CAT-4 administered by this school board in 2014 and 2015. The data were available for 57 grade 5 students from phases 1 and 2 samples ($N_{phase\ 1}$ = 22 and $N_{phase\ 2}$ = 35) and revealed significant positive correlation between students' IL and their reading scores (Pearson r= .58, p<0.01). Furthermore, the results suggest that eight students who were reading below the school-board CAT-4 average score of 491 (measured in grade 3) showed higher gains in IL than their average- and above-average-reading peers. Specifically, these improvements are notable for *Planning, Searching* and total TRAILS scores, albeit not statistically significant.

To explore if the length of teacher experience to implement ISIS-21 may have impact on students' IL skills, we also compared the TRAILS gains of two grade 5 classes who were taught by the same teacher in phases 1 (N=24) and 2 (N=35). The results show that with the exception of skills in *Using information* where the difference between the classes is almost nonexistent, the gains of students in the class where the teacher used ISIS-21 for the second year are consistently higher than that of students from phase 1 yet non-significant.

3.2 Examples of ISIS-21 work

To illustrate how the students were able to use the ISIS-21 features to complete the phases of the research process, we have included fragments of one student's ISIS-21 work. The screenshots in Figure 2 shows how the student started planning the research process by describing her understanding of the task and defining the big and little questions.

Figure 2: Example of Big and Little Questions steps

By brainstorming her background knowledge about the topic, the student identified what she needed to learn about her topic and formulated a list of smaller research questions, which she also colour-coded. The student used the little questions to determine the main concepts and related terms. Then she arranged them into search strings by using Boolean operators to search for the kinds of information and sources that contain this information. In addition to showing the resources and tools the student used to complete her search, Figure 3 presents a list of marked sources she selected to answer one of her small questions.

Figure 3: Example of Select step

As shown in Figure 4, the student attempted to organise the information she collected in the form of notes, quotes and/or paraphrased text from the selected sources. The colour-code she assigned at the planning phase of research to each smaller question were applied by the system to the key ideas she summarised from each source to answer that specific question. This feature helped the student organise the notes she took from different sources and synthesise them to answer her big question.

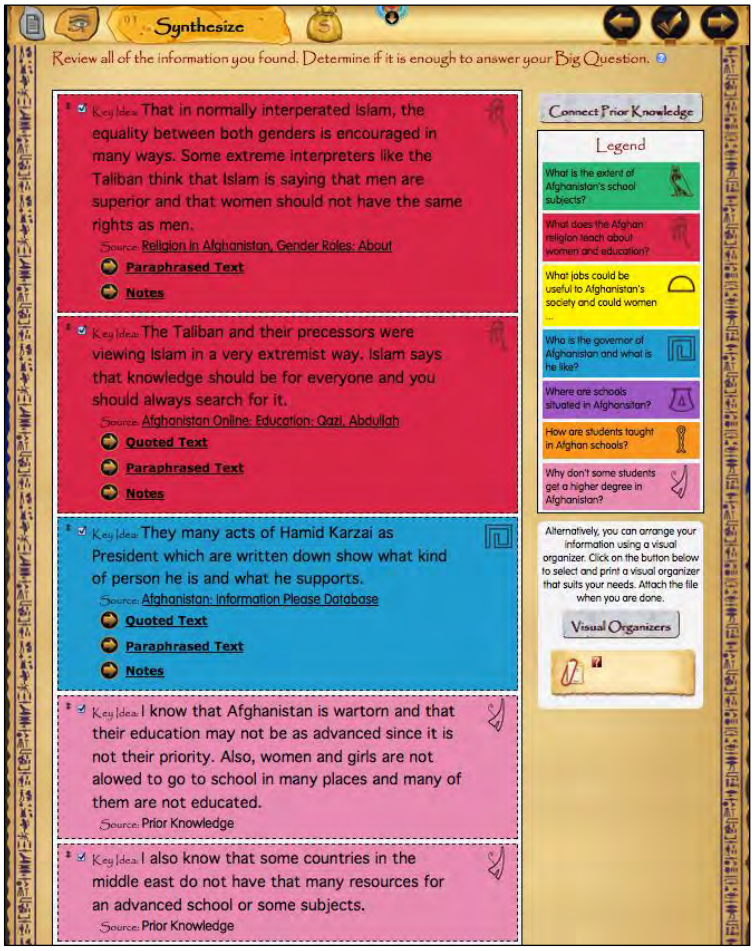

Figure 4: Example of Synthesise step

3.3 Students' and teachers' experience using ISIS-21

The self-reported data we collected from students and teachers provide us with a picture of their experience with ISIS-21 and the inquiry process. In phase 1 after having finished their ISIS-21 inquiry project, 79% of the students reported having learned important IL-related skills. Among the strategies the students would use when they complete a future inquiry process, *Searching* (selection of key words, use of logical connectors, design of search statements and evaluation of sources) was reported more frequently (by 23% - 10%), than *Planning* (6.3% - defining big and little questions) and *Using information* (5.2% - paraphrasing). Reviewing and paraphrasing, as well as formulating big questions were reported as hard to do steps in ISIS-21. The students also characterised the inquiry process as time and effort consuming. In particular, 70% and 46% of students respectively reported that it had taken them too much time or effort to complete the ISIS-21 steps. In this regard, it is not surprising that 53% of students found ISIS-21 easy to use and only 40% reported that they would like to use ISIS-21 again.

Phase 1 teachers' perceptions of their students' experience with ISIS-21 were more optimistic than that of their students. Four of six teachers thought that it was easy for their students to use ISIS-21. Five of them reported that their students learned how to do research with ISIS-21 and would be willing to use ISIS-21 in future. Only one teacher reported that using ISIS-21 was too effort consuming. Yet five of them agreed that it was overwhelmingly long to complete all steps of ISIS-21. The time it took to implement the project in classroom instruction was a concern for teachers. The issue of time was raised when teachers referred to pre-teaching the IL-related concepts and providing the necessary guidance to students to complete these steps in ISIS-21.

In an interview about her experience with ISIS-21, the phase-two teacher also highlighted the comprehensiveness of the tool and therefore the amount of time it took to teach the inquiry process, before her students were able to complete the ISIS-21 phases. She reported that having integrated ISIS-21 into classroom instruction for the second consecutive year was beneficial as she developed a more comprehensive understanding of the inquiry process. She also became more comfortable and instrumental in supporting her students' use of the software to achieve the intended outcomes. This teacher felt that either with or without ISIS-21, she was now able to more effectively teach the steps of the inquiry process to students of any grade level, ranging from early elementary to secondary. From the teacher's perspective, the most valuable aspect of completing the ISIS-21 projects was exposing students to the diversity of sources and making them meaningfully apply the criteria for selecting pertinent and high quality sources to create their own knowledge on the topic of interest to them.

4. Discussion

We were pleased with the results of this study as we were able to establish the feasibility and importance of using ISIS-21 in classrooms to promote the development of IL skills in late elementary students. In terms of student learning, we found:

- a significant increase in students' IL skills as a result of using ISIS-21 and this finding is consistent throughout all of the phases of the project;
- there is an important link between student reading comprehension and IL skills. The results indicate that use of ISIS-21 benefited the greatest the lower reading students, as their gains in IL skills were higher than those students who scored average and above-average in grade 3; and
- there is also an important link between using ISIS-21 and the development of self-regulated skills, especially in the areas of task value and reflection.

While the results point to, but given the study design, do not enable us to confirm the positive impacts of using ISIS-21 on student learning, we believe that this study represents an important first step in learning how a knowledge-based tool such as ISIS-21 can be used to positively impact student learning and the teaching of IL skills. While there may be alternative explanations to the ISIS-21 treatment effects given the lack of a control group, they may not be likely as the subject matter of ISIS-21 is not covered in the usual coursework of students, thus limiting any history effects, testing effects seem improbable, and maturational influences are an unlikely explanation of pre-post differences. Because students were not selected based on extremes scores, regression effects should also be ruled out.

In terms of students' and teachers' perceptions towards using ISIS-21, we learned that:

1. While the design of ISIS-21 addresses each important IL sub-skill, according to the students' feedback, the tool is quite heavy and comprehensive to use. Students were seen to value the more straightforward features offered in ISIS-21, such as allowing them to build search strategies and to use the evaluation criteria rubric within ISIS-21, as compared to those requiring more complex skills such as defining research questions and synthesising information.

2. Teachers found the use of ISIS-21 was valuable and that their students both learned and enjoyed using ISIS-21. However in keeping with principles of the expectancy theory, there was some concern about the amount of time it took to implement the tool in classroom instruction. Having said this, it was interesting to learn that one teacher employed what she had learned from using ISIS-21 in subsequent inquiry tasks with her students.

As a result of these findings, a Flexible Mode has been designed with ISIS-21, whereby various steps have been combined. The intent here was twofold: (1) to reduce the "heaviness" of the tool and (2) to provide more flexibility on how and when ISIS-21 may be used. For example, if a student feels s/he does not need the scaffolding provided within the tool, they are able to complete only those steps for which they lack an understanding.

The study suffers from a few limitations including the relatively small sample size and high variance in scores affected the statistical power of the analyses, hence the next phase of research on ISIS-21 should be a true experiment with a control group. Except for the use of TRAILS, other outcome measures were not used systematically at all times of testing and throughout all ISIS-21 phases. Lastly, there was a moderate correlation between the measures.

At the same the study allows us to conclude that not only does student learning potentially benefit from using ISIS-21, but late elementary teachers stand to benefit from the scaffolding offered within ISIS-21 as well. Given the current gap in teachers' understanding of how to teach IL skills, ultimately we hope that evidence-based knowledge tools such as ISIS-21 will be widely implemented in schools, without major adjustments to either normal school schedules or budgets, because IL tools are in need, and a tool such as ISIS-21 is available without charge, is easy to use, and is designed to support the development of important IL skills in a host of curricular areas.

Without the development of these skills early on, the majority of students will continue to construct poor search strategies, retrieve inappropriate material, and incorrectly analyse and synthesise what they have found. These weak IL skills will follow these students into the workplace and into their personal lives and, if uncorrected, will limit the potential of generations of North Americans in the Knowledge Economy.

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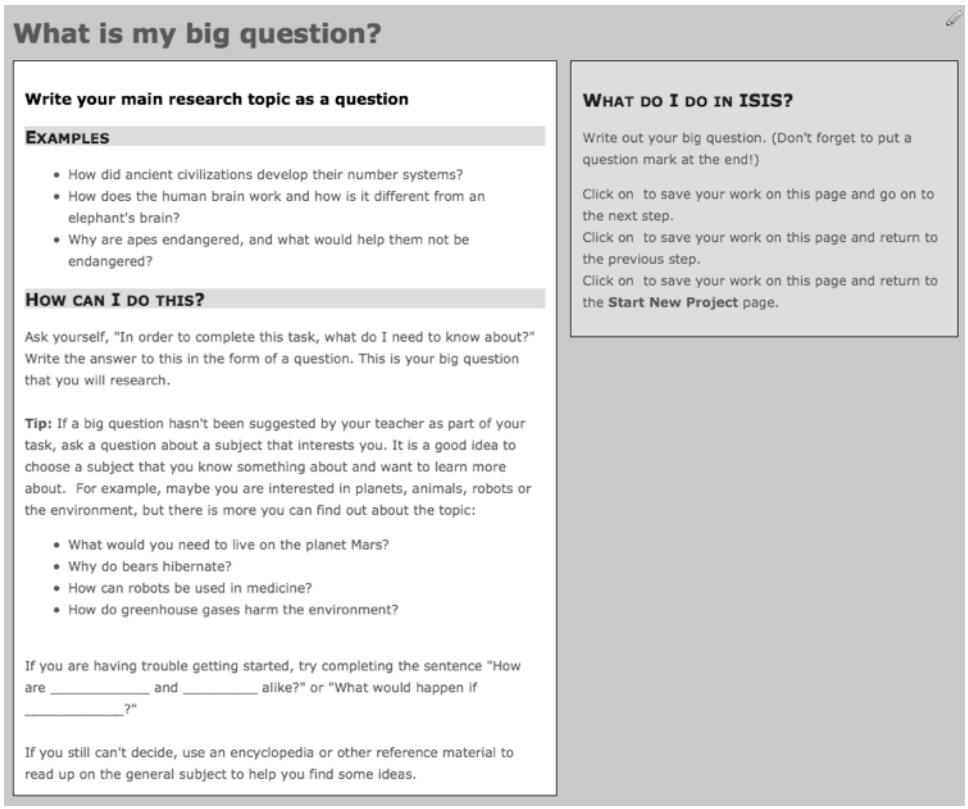
Appendix 1

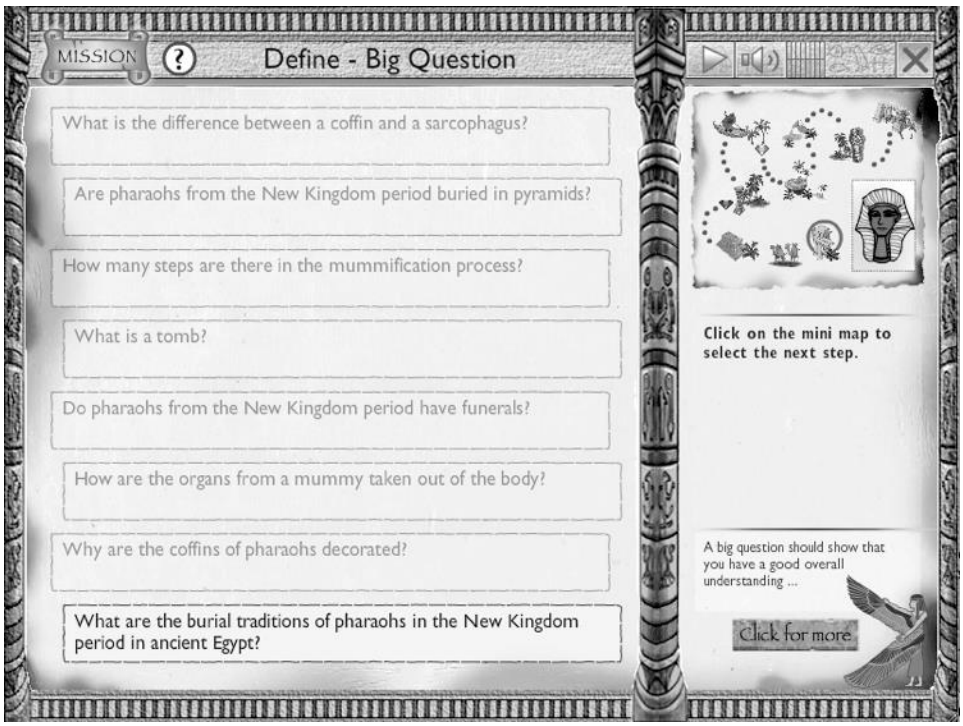
Selected examples of screens from ISIS-21

Phase 1: Define step

In the Plan phase (Start, Define, Brainstorm, Keywords, Combine Keywords, Resources) students plan and prepare the groundwork for their inquiry process. The Define step, allows student to think about important and meaningful questions they wish to research. From here they will break the big question down into sub-questions, distill these questions into main concepts or keywords, create logical relationships between the concepts, and determine the best source(s) to use in order to help answer each of the questions. See the next page for the explanation of the support.

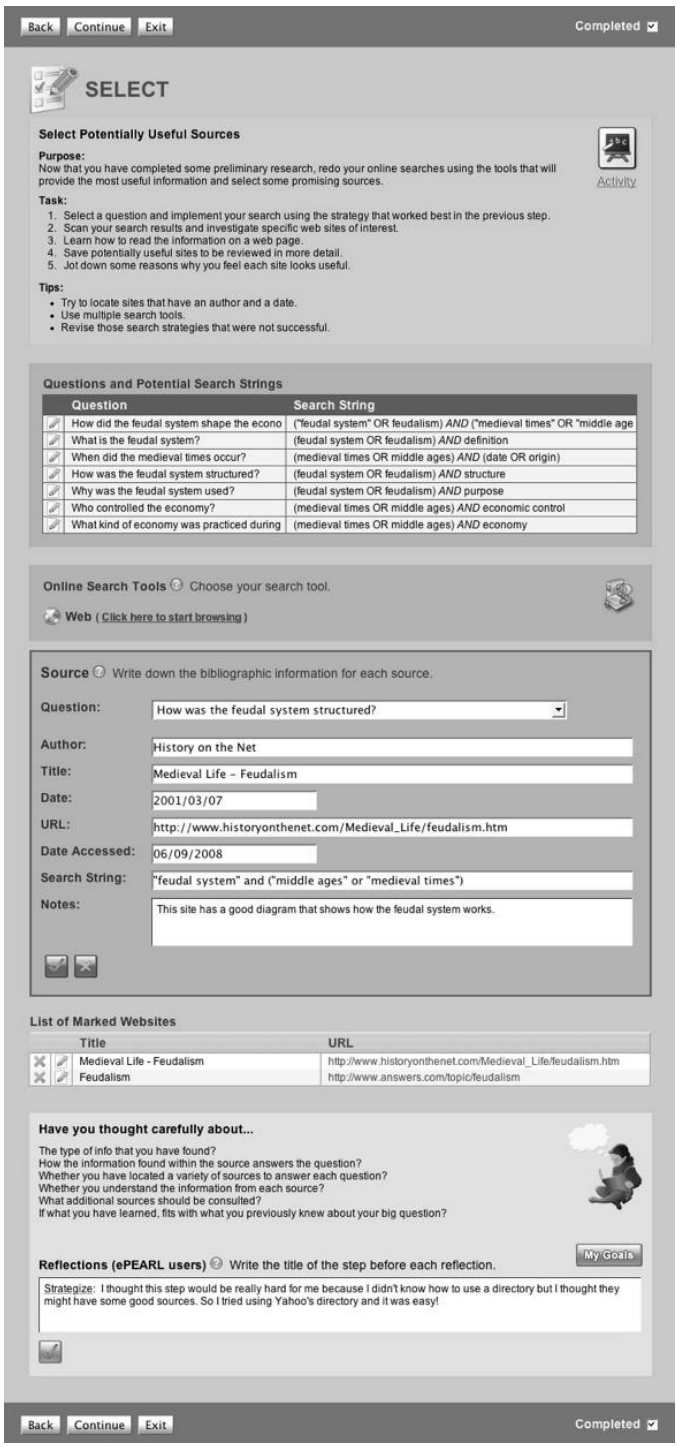


In-Context Help: Big Question:
The ISIS-21 Help provides an explanation of the feature, examples, and pedagogical and technical instruction on how to complete the given step.



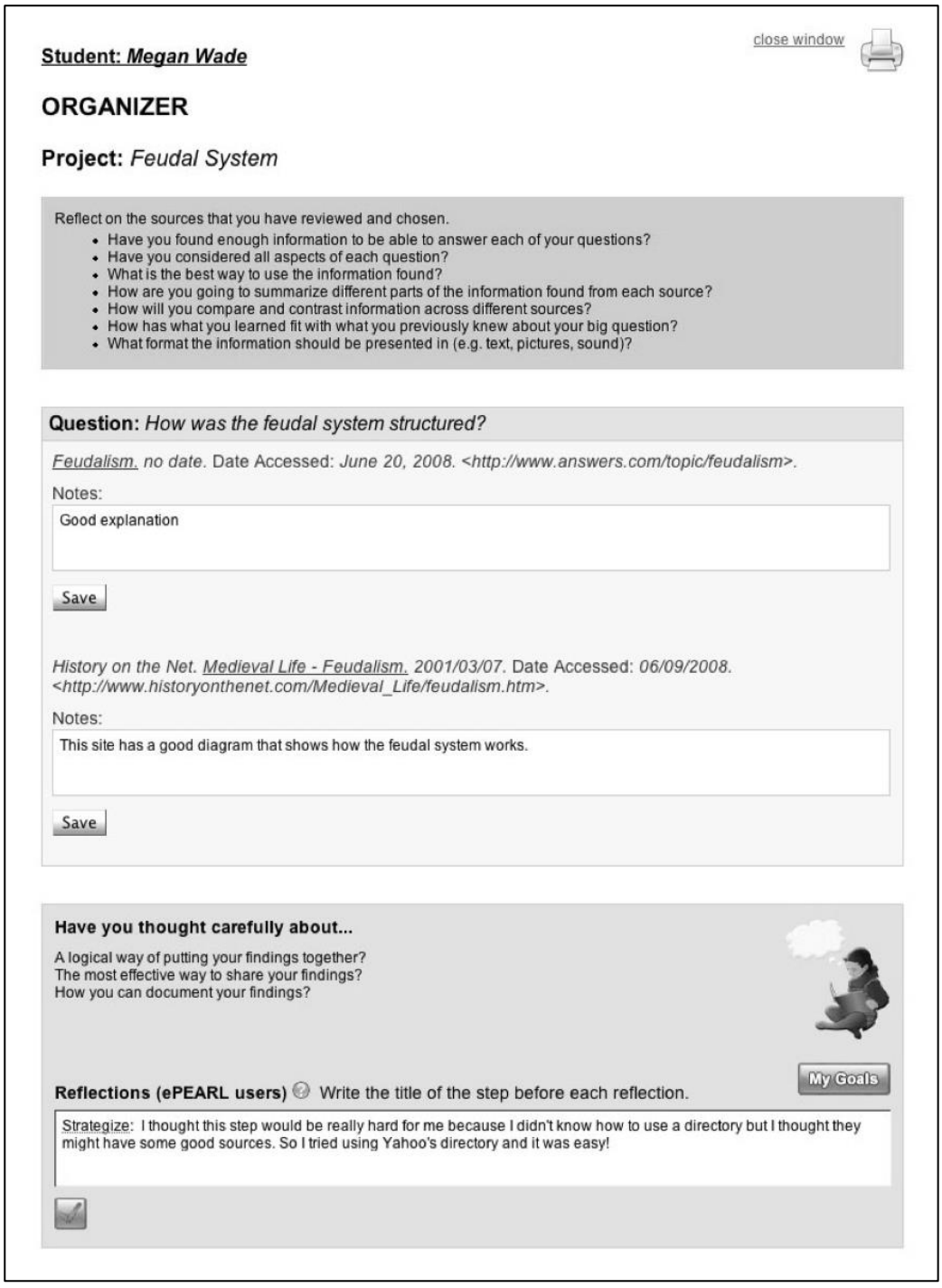
ISIS-21 Game: Big Question step

Clicking on the Activity icon will bring the user to an interactive game for further instruction on each of the steps.



Phase 2: Select step

In the Search phase (Strategise, Select, Review), students actively search for answers to each of their questions, forming judgments about the relevancy and suitability of sources as they are discovered. In the Select step students are able to store the descriptive information for each potentially relevant source.

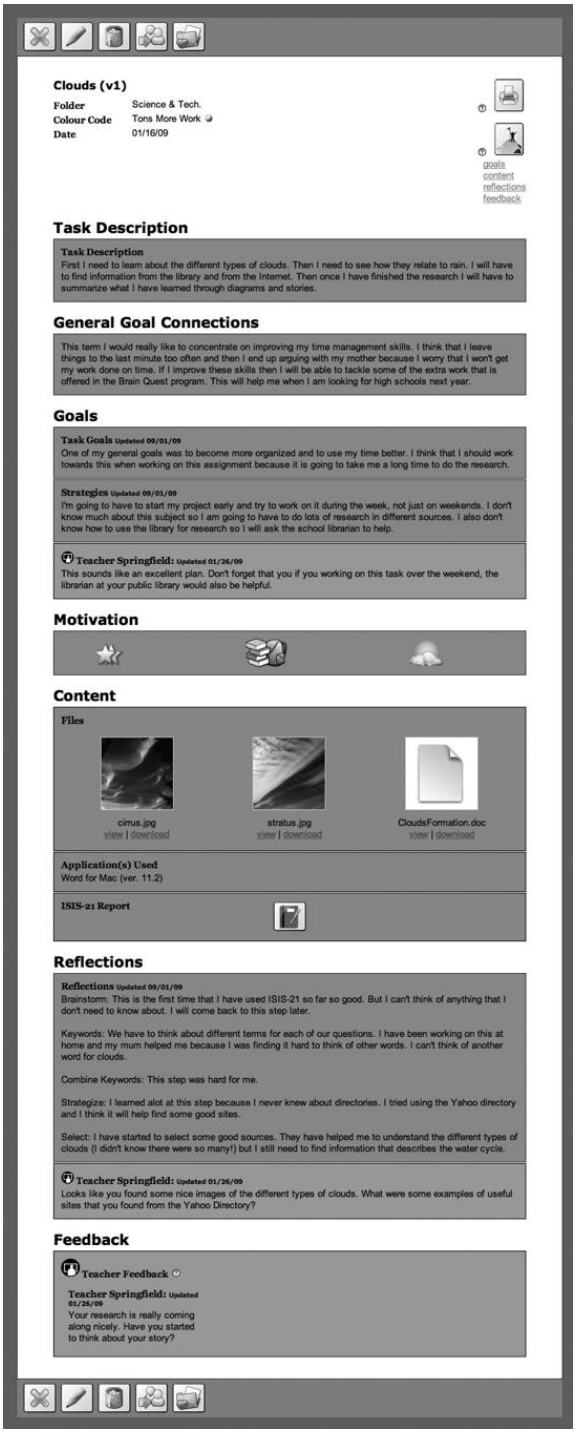


Phase 3: Organiser step

In the Use phase (Note taking, Synthesise, Acknowledge, Format) students read each source for deeper understanding, make notes, compare and contrast the information, form new knowledge from what they have learned and use multimedia to communicate this knowledge. The Organiser feature provides a compilation of the sources that have been selected for use in the final "product" of the research. Each source is automatically formatted according to MLA and provides an active window for note taking.

Appendix 2:

Example of an ePEARL Artifact (linked to ISIS-21)



Clouds Artifact

Under *Content* there is an ISIS-21 report of the research that was conducted, along with the three files representing products of the research.