

**USING EFFECTIVE INFORMATION
SEARCHING SKILLS
TO SOLVE PROBLEMS**

By

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ABSTRACT

Problem-based learning (PBL) is an instructional approach that is organized around the investigation and resolution of problems. Problems are neither uniform nor similar. Jonassen (1998, 2000) in his design theory of problem solving has categorized problems into two broad types - well-structured and ill-structured. He has also described a host of mediating skills that impact problem solving outcomes. However, this list of skills is not exhaustive and in view of the utility of the Internet as an informational repository, this study examined the need for effective information searching skills to be included in this list.

This study was aimed at studying how students solve well and ill structured problems and how different Internet information seeking strategies can be used to engage in problem solving. This study devised and empirically tested the efficacy of an interventionist conceptual model that maps the application of different information seeking techniques to successfully resolving well and ill structured problem types. The intervention helps to better understand the influence of information searching skills on problem solving performance and the various problem solving strategies students can adopt in approaching problem solving. The contrasting patterns of navigational path movements taken by students in seeking information to resolve ill and well structured problems were also investigated.

A mixed methodology research design, involving a mix of quantitative and qualitative approaches was used in this study. The research site was a polytechnic in Singapore that has implemented problem-based learning in its

curriculum design. A first year class of 25 students were the sample population who participated in this study. Six problems from the curriculum were chosen for this study – three well-structured and another three ill-structured problems.

The research findings of this study inform that information searching skills indeed play an important role in problem solving. The findings affirm the need for students to be systematically instructed in the skills of information searching to be aware of the complexities involved in information seeking and accomplish desired problem solving goals. This study has also shown that well and ill structured problems demand different cognitive and information seeking capabilities. Well-structured problems are easily solved and come with singular correct answers. The information searching necessary for solving well-structured problems is constrained and readily manageable. Thus, students only have to be acquainted with fundamental information searching skills to solve well-structured problems. On the other hand, ill-structured problems are messy and contain a number of unknown elements. There are no easy prototypic solutions. Subsequently, the information needs of ill-structured problems are usually complex, multi-disciplinary and expansive. Hence, students have to be trained to apply a more advanced set of information searching skills in resolving ill-structured problems.

This thesis has not been submitted for a higher degree to any other university or institution. Approval from Ethics committee has been obtained in carrying out the research work of this thesis (HE25AUG2006-D04840).

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CHAPTER 1 – INTRODUCTION

Background of the study

Solving real-world problems is an effective learning activity that promotes meaningful learning in formal educational settings. Meaningful learning is driven by goal-directed behaviours and needs to support cognitive processes involving active manipulation, intentional reflection, purposeful regulation, analytic application and collaborative/conversational discourse. Since problem solving forms the backbone of the bulk of activities taking place in the non-school world, creating instructional environments that simulate real-world working contexts enables learning to be meaningful. A problem comprises an unknown state of phenomena in which one might have a goal but is unable to reach that goal. This intellectual endeavour is shaped by numerous considerations such as social, cultural, historical and economic factors. Moving from the state of the unknown to known encompasses the operational processes of problem solving. Some of these processes include understanding the objectives of the problem, dissecting the problem into its constituent elements, devising possible solutions and testing outcomes to successfully deconstruct the given problem. Being able to successfully solve problems is more than just accumulating knowledge - it involves the development of flexible, cognitive strategies that help analyse different problem situations to produce meaningful learning outcomes. Embedding an

approach of problem solving in learning facilitates the application of near and far transfer of relevant skills and competencies within applied contexts. Other learning outcomes attainable from engaging in problem solving include deeper understanding of content knowledge and application of expertise in real world situations. Hence, students become more empowered and motivated in being involved in the learning process.

David Jonassen (1997, 2000) in his design theory articulates a typology of different kinds of problems that range upon a diverse continuum spanning from well-structured to ill-structured. Well-structured problem types typically present all the limited elements of the problem; engage a bounded number of rules, axiomatic principles and concepts that are organized in predictive, sequential and prescriptive manners. Well-structured problems contain predominantly singular, convergent, correct answers and are underpinned by structured, preferred solution processes. Algorithms and story problems are archetypal examples of well-structured and fairly simple problems. On the other hand, systems analysis, design and dilemmas are prototypical ill-structured or wicked problem themes. Ill-structured problems contain many alternative solutions, are ambiguously defined with unclear goals, unspecified constraints, lack of relevant information and multiple criteria for evaluating solutions. These problems tend to be more complex and emergent. Ill-structured problems need to be approached from different and often conflicting interpretive perspectives and require learners to express their personal opinions or stances on the problem (Jonassen 1997, 2000).

Individual differences in various skills-based competencies mediate and affect the modalities of problem solving. Some of these predictor skills regulating the processes of problem solving that were examined by Jonassen include domain and structural knowledge fluency, cognitive capabilities, metacognitive skills and affective dispositions. Domain knowledge refers to the amount of discipline-specific content knowledge related to a domain one has in influencing his/her ability to comprehend the problem and generate appropriate solutions. Cognitive styles and skills, representing patterns of internal thinking, control the ways in which individuals process and reason about information to enable problem solving. Metacognition relates to the awareness of how one learns, the ability to judge the difficulty of a problem solving task, monitoring of comprehension, use of information to achieve a goal and being observant of one's learning performance progress. Affective dispositional elements such as attitudes and beliefs about the problems, problem domains and learners' abilities to solve the problem directly impact problem solving skills.

However, this list of mediating skills presented by Jonassen is not exhaustive. In light of the widespread reliance upon the Internet as an important information repository, effective information searching and use becomes critical to successfully accomplishing problem solving (Jakes, Pennington and Knodle, 2002). The Internet indeed serves as a powerful informational and learning tool since it hosts large amounts of information that can be readily accessed. However, finding relevant information in the expansive landscape of the Internet is not an easy or simple task as it requires

a variety of skills such as understanding the different Internet tools, knowledge of search techniques, cognitive capacity to organize searches, and ability to efficiently execute the searches. These skills are sophisticated and cannot be easily learnt by students on their own. Without being subjected to formal training in information searching literacy, the possibilities of students performing haphazard, disorganized searching and appropriation of unreliable information are high.

Statement of problem

The set of enabling skills expounded by Jonassen as influencing problem solving outcomes needs to be expanded to include Internet information searching capabilities. Effective application of information searching skills to acquire and utilize relevant information found in the Internet in devising robust solutions is essential to productive problem solving. However, these skills are too complex to be readily mastered by students independently since the Internet is an unregulated repository of information resources lacking order and organization. At present, there are no formal instructional curricular programmes in Singapore educational institutions that are designed towards systematically teaching students practical information searching competencies. This could potentially lull students into a false sense of complacency about their actual Internet navigational abilities and be ignorant of the difficulties involved in locating relevant information.

In order to properly train students in the complexities of Internet information searching to support problem solving, the relationship between the effectiveness of different Internet information searching strategies and

productiveness in problem solving needs to be established. Information searching strategies have to be differentially employed in engaging in problem solving by taking into account the structure of given problems. Hence, the application effects of different Internet information searching techniques upon the performance of solving well and ill structured problem representations is an important area of research that merits further investigation.

Research questions and hypotheses

A mixed methods research design was used in this study and so both research questions as well as hypotheses were developed. Descriptive, exploratory research questions in alignment with the design requirements of the qualitative research paradigm were framed whilst hypotheses were formulated to quantitatively test relationships between specified constructs.

Research questions (for qualitative analysis)

The following research questions were qualitatively investigated in this study:

- 1) How do students view the Internet as an information tool to approach problem solving? What are the primary strategies and techniques they adopt in using the Internet to search for information?
- 2) What are the structural attributes of well and ill structured problems and the design elements involved in crafting scenario-based tasks for these problems? What are the differences in the ways students approach solving well and ill structured problems and the subsequent processes they employ in constructing solutions to these problems?

- 3) What is the nature of the relationship between different Internet information searching skills and students' performance in solving well and ill structured problems?

Research hypotheses (for quantitative analysis)

Path compactness and stratum metrics (McEneaney, 2001) are two key constructs that enable better understanding of the structural character of students' navigational pathways in searching for information and solving problem tasks. Hence, these metrics have been used in developing the research hypotheses for this study. Stratum and compactness are respectively the mathematically computed indicators of the linearity and connectedness of network-based structures defining users' online navigational visitations.

The following are the hypotheses that were quantitatively analysed for their validity:

- 1) There is a significant difference between the path compactness metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.
- 2) There is a significant difference between the path stratum metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.

Significance of study

This study examined the Internet information searching habits and problem solving behaviours of a class of students in a polytechnic institution in Singapore. A polytechnic in Singapore's context is an institution of higher learning that offers an academic route of learning to high school graduands (approximately 16-18 years of age) who wish to pursue as tertiary students a full-time diploma in a disciplinary field of interest to them. There are variety of courses offered by a polytechnic emphasizing the development of both discipline specific content expertise and life skills. These courses span the gamut from industrial arts to applied sciences to cater to a wide range of audience. Besides, full-time courses for students a polytechnic in Singapore also offers part-time night courses for working adult learners to upgrade their skills and competencies. The distinctiveness of the polytechnic involved in this study is that it is the first in Singapore to have implemented an alternative pedagogy of problem-based learning at a systemic level. This study set out to investigate polytechnic students' abilities to locate, apply and use information found in the Internet within a problem-based learning setting. Subsequently, an integrated interventionist framework for designing and implementing an instructional programme that systematically trains students to become fluent information searchers and competent problem solvers was framed and empirically validated. The findings of this study will enable educators involved in the field of problem-based learning to better understand the nature of the relationship between different Internet information searching strategies and effectiveness in solving well and ill structured problem themes. They could

then adaptively use the proposed framework to mount relevant training programmes in their home institutions to raise the information searching and problem solving proficiencies of their students.

Limitations of study

There were some limitations in the theoretical conceptualization and actual implementation of this study:

- 1) Due to logistical, scheduling and manpower constraints, the polytechnic was able to assign the researcher only one class of 25 students for the conduct of this study. Thus, it was not possible to collect a larger sample of students to ensure a higher degree of reliability and comprehensiveness during the analysis phase to achieve enhanced empirical validity and population representation. Moreover, the allotment of one class resulted in a mixed-method design experiment approach being prototyped in collecting and analyzing longitudinal data in this research study. This precluded the more accurate randomized well-matched comparison group design involving control and experimental groups from being implemented.
- 2) The well-structured problems that were administered to students ought to be of the same level of cognitive and conceptual difficulty in order to make valid comparative measurements of the intervention's effects on students' problem solving performance. This criterion is similarly important in the case of ill-structured problems assigned to students. This key consideration was indeed taken into account during the selection of problems for this study. However, unavoidably, this was not

truly possible due to constraints of limited choices imposed by the pre-defined instructional curriculum and its associated fixed set of problems - the development and implementation over which the researcher had no control.

- 3) Considering the prolonged period of duration over which the course of this research study has been carried out, time is to some extent an influencing variable in the growth and maturation of competent information searching skills amongst participant students. Though, a repeated measures experimental approach was adopted to address this issue, the time factor may still not have been completely controlled for and its impact upon the results of this study not totally eliminated. It is to be noted that students usually join polytechnics after completion of their high school education and learning activities in high schools tend to be more structured, organized and didactic than in polytechnics where greater learner autonomy and regulation is placed upon students.

Organization of text in thesis

The following second chapter of this thesis will be a presentation of selected research literature related to this study. The review of literature will form the theoretical basis underpinning the research goals, direction and design of this study. Reviewing the work of other researchers in information literacy and problem-based learning will help map out the research that has been accomplished thus far in this important area and buttress the need to carry out the research as planned in this study in analyzing the role and impact of information search skills on problem-based learning pedagogy. The third

chapter will discuss the research methods and procedures conducted in this study. The underlying rationale behind the choice of specific research methods will be explicated to inform readers on the fit between these methods and research aims of this study. In the fourth chapter, pre-intervention qualitative data analysis findings will be described to present the empirical research results that highlight the lack of competency in the information search proficiencies of students. The fifth chapter will build upon the outcomes described in the fourth chapter to explain the relevance of the information search skills training interventionist framework implemented in this study to explore the relational power of search strategies on problem solving efficacy. This framework was developed to explore the impact of different Internet information searching skills on students' abilities to solve well and ill structured problems. It is based upon an inquiry-based learning model and consists of a repertoire of Internet information searching strategies that could be employed by students to enhance their problem solving capabilities. The sixth and seventh chapters elaborate upon the results from the post-intervention quantitative and qualitative analyses findings of data collected. The findings will seek to investigate the validity of the articulated hypotheses and find answers to the overarching research questions. The final eighth chapter summarizes the conclusions of this study and details the pedagogical implications for instructional practices. Possible areas of further research have also been explored in this chapter.

CHAPTER 2 - REVIEW OF THE LITERATURE

Learning as a meaningful activity involves processing and applying knowledge in real-life situations. Problem-based learning (PBL) is one such epistemological orientation that promotes meaningful learning by situating learners as problem-solvers in tackling different types of problems (Ho, 2004). When the problem is one that interests students, they are much more likely to become stakeholders in problem solving (Eisner, 1994). The Internet as a prominent source of information serves an important role in supporting problem solving endeavours by enabling flexible and timely access to digital information (Nachiamas & Gilad, 2002). Nowadays, computers and the Internet are common fixtures within the educational landscape (Levin & Arafeh, 2002). The challenge now is to reflect upon how useful Internet technologies are in enhancing learning outcomes and harnessing new opportunities created by these technologies (Rodriguez & Knuth, 2002).

Though the Internet readily facilitates immediate access to information, in reality, the Internet is a complex repository containing a huge maze of unregulated information from a variety of sources. Information literacy skills, particularly information searching competencies are critical in locating and using information found in the Internet (Stern, 2002). These skills are complex and not easily learnt independently by students (Gruwel, Wopereis & Vermetten, 2005). It was found that students who regularly use the Internet

tend to be familiar with its interface but lack rigorous information literacy skills to become competent information seekers and users. For example, students knew and had used popular search engines but were unable to craft precise search terms that would have optimised their search efforts and produced the most relevant list of search results (Muthukumar, 2005; Schaster, Chung &Dorr, 1998). Hence, there is a need to methodically train students in these skills to raise their information searching proficiencies to become better problem solvers and learners. This study looks in-depth at how the Internet can be effectively employed as a learning tool in engaging students in problem solving and the application of different information searching skills students need to be trained in to successfully perform problem solving.

This review of literature begins with an overview of the concept of problem solving as well as the broad definitions and attributes of problem-based learning. Next, it looks at the design theory of problem solving and related key principles that underpin this study aimed at better understanding problem solving goals, processes and outcomes. Then, the review elaborates on the importance of information searching literacy capabilities in engaging in problem solving. This is followed by a discussion on how the Internet could serve as a vital informational and educational platform in improving the quality of learning experiences. Since the Internet is a vast and complex network of information resources, the Internet itself offers a number of search tools for effective information searching to be accomplished. Next is an analysis of the efficacies of different cognitive techniques and search strategies in facilitating successful Internet information searching. Finally, the literature review

concludes by examining some of the identified information search patterns resultant from users' Internet navigations as well as dynamic measures that could be employed to study the structural attributes of these search patterns.

Problem solving

Problem solving can be defined as the goal-directed sequence of cognitive operations in finding the unknown to resolve a problem situation (Anderson, 1980). These operations require two important attributes. Firstly, the problem solvers need to construct a mental representation or model of the problem, known as the problem space (Newell & Simon, 1972). The problem space is the representation of the problem, including the understanding of the problem state and goal state and how best to move from the initial state to the goal state through activating a catalogue of operators (Wood, 1983). Such attempts at problem space representation allow students to take ownership of the problem solving activity by better understanding the demands of the problem and cognitively organizing viable problem solving strategies. Secondly, problem solving requires some activity-based manipulation of this problem space. This involves students identifying what they already know, what they need to find out through further questioning and then drawing links between the two in seeking possible solution pathways. Problem solvers need to exercise the best of their analytic, argumentation and interpretive abilities in constructing valid schematic conceptions of the problem and achieving acceptable problem resolution outcomes. The focus of learning during problem solving is the problem itself. Students acquire new knowledge and learn by solving problems.

Success in constructing and manipulating the problem space to solve a problem is dependent on the learner's understanding of the conceptual schema for different problem types. If the learner possesses a complete schema for a particular problem type and encounters a problem of this genre, solving the problem requires the learner to map the existing problem schema onto the problem and applying the procedure that is part of the known schema (Jonassen, 2000). Lester (1983) has argued that students' problem-solving ability develops slowly over a prolonged period of time and in trying to raise their problem solving competencies, they must be given opportunities to solve many problems and students will benefit greatly from systematically planned problem-solving instruction. Problem tasks can vary in terms of the skills and knowledge competencies needed to solve the problems. Depending upon the structure, disciplinary scope and characteristics of the problem tasks, tackling a broad range of problem situations require different degrees of analytical and intellectual reasoning (Enright & Norback, 1997). Recognizing the differences between problem types and understanding the variations involved in the problem solving processes for these problem types improves problem solving instructions and enables students to be more effective problem solvers. This is a subject matter that is investigated extensively in this study.

Problem-based learning, its attributes and processes

In this section, common definitions of problem-based learning (PBL) and the typical attributes as well as processes of PBL will be examined to better understand the pedagogical character and requirements of a PBL environment.

Problem solving activities and outcomes form the core of a problem-based learning (PBL) epistemic approach. PBL is an instructional methodology that centrally focuses upon the design and dynamics of problem solving processes. Various wide-ranging but at times overlapping definitions of what constitutes problem based learning have been proffered by researchers and educators. Savery (2006) describes PBL as an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice and apply knowledge to solve problems. Biggs and Moore (1993) characterize PBL as the learning of knowledge in an embedded context that informs a need for that knowledge. Similarly, Boud and Feletti (1997) explain PBL as being grounded to the underpinning belief that learning is most effective when students are co-operatively engaged in learning in contexts in which the knowledge is to be used. Fogarty (1997) defines PBL as a curriculum model designed around real-life problems that tend to be ill-structured, open-ended or ambiguous. It is multi-disciplinary and requires the application of knowledge from different fields of expertise in solving authentic problems. Tan (2004) posits that problem-based learning could be viewed as an instructional strategy that enables development of critical thinking through verbalizing and making visible the thinking process. He

further argues that PBL encompasses a progressive active-learning outlook and learner-centered approach where unstructured problems, either real world or simulated complex problems are used as the entry point into the learning process. In summary, PBL can be described as a pedagogical orientation that encourages students to develop critical thinking and self-directed learning skills by actively solving a repertoire of different problems that function as the organizing centre and context for building up content knowledge bases in multiple disciplines.

A meta-analysis of 20 years of PBL evaluation studies conducted by (Albanese & Mitchell, 1993; Vernon & Blake, 1993) concluded that a PBL approach to curriculum matched traditional approaches in terms of conventional tests of knowledge but students who studied using PBL displayed better clinical solving skills. A study of graduates of a physical therapy program that utilized PBL found that these graduates performed equally well with PBL or traditional approaches but students preferred a PBL approach. Anecdotal reports from PBL practitioners suggest that students are engaged when learning through PBL.

The widespread adoption of PBL instructional approaches by different disciplines and content domains has produced some misconceptions and misapplications of PBL as well (Maudsley, 1999). Some of the possible causes for failed PBL initiatives include lack of research on the types of problems to be used, insufficient commitment from teaching staff, use of inappropriate assessment methods that do not match the learning outcomes sought in problem-based programs and application of evaluation strategies which do not

focus on key learning issues and are implemented far too late (Boud & Faletti, 1997).

PBL as an educational approach begins with the presentation of a problem or question (Duffy & Cunningham, 1996). Problems could be either real-world or simulated and serve as the motivational driver in providing a meaningful context for students to manage their learning. These problems generate patterns of deep learning, arouse learners' curiosity and facilitate their exploration of a myriad of issues from multiple and often conflicting perspectives in devising viable solutions (Hmelo & Evensen, 2000; Savery & Duffy, 1995). Learners are called upon to challenge current attitudes, understandings and competencies, thus encouraging students to entertain multiplicity in views and reconcile conflicting standpoints to forge integrated frameworks of understanding (Tan, 2004). This encourages skills learnt through PBL to be transferred to real world contexts (Bransford, Brown & Cocking, 2000). In the course of analyzing and decoding problems, a suite of recursive learning activities take place involving experimentation, data collection, reflection, critiquing and communications (Hmelo & Evensen, 2000; Savery & Duffy, 1995).

Through PBL, students develop hypothetical-deductive reasoning skills by acquiring relevant data, synthesizing the data and testing them through acquiring additional data (Wilkerson & Gijsselaers, 1996). The end result is an independent student capable of life-long learning. Other learning benefits associated with PBL from problem solving outcomes include improvement of students' levels of curiosity and stimulation. This can bring about motivation by

questioning, searching for information and finding knowledge rich solutions within the real world. Enabling students to seek solutions in a safe environment allows for critical thinking within groupwork and provides opportunities for growth with learners seeing and observing one another.

Learning in a PBL environment is fundamentally self-directed and requires students to exercise self-reflection, metacognition and questioning (Weissinger, 2004). Students have to independently rely upon and use a variety of resources in building up their content and conceptual knowledge. These resources could be media, electronic or print based. Barrows (1994, 1996) notes that learning within a PBL environment requires the integration of knowledge from a wide range of disciplines or subjects. During self-directed learning, students have to access, study and apply information from all disciplines related to resolving a given problem and build up strong knowledge structures – just as people in the real world who have to recall and apply information integrated from diverse sources in performing their work. Students could be tasked to work in small groups with high levels of participatory interaction and collaborative synergy in brainstorming for workable solutions (Tan, 2004). Engaging in collaborative problem solving promotes collective inquiry consisting of iterative cycles of reflection and action in cooperation with a group of peers (Bray, Lee, Smith & Yorks, 2000). This facilitates the co-construction of knowledge within a group environment where the new knowledge is intrinsically considered as the common property of the group. In the context of such an autonomous, non-prescriptive learning environment, the teacher's role changes from one of being authoritarian to one of being a

cognitive coach who facilitates learning to take place (Stepien & Gallagher, 1993).

Design theory of problem solving

According to the design theory of problem solving of Jonassen (2000), the ability of a learner to solve problems is a function of the nature of the problem, the way that the problem is represented to the solver, and a host of individual differences in skills possession mediating the process. The theory attempts to link the acquisition of prerequisite skills to specific models of problem solving instructions based upon a range of problem solving outcomes. Alexius Smith Macklin (2003) found in his study that applying this theory in the instructional design of programs in academic libraries to be richly helpful in creating successful instructional curriculum. Rather than prescribe a generic formula for success, the theory guided in designing effective instructional programs that recognize diversity amongst disciplines and institutions. The design theory of problem solving was a key component of the theoretical basis for Lee and Nelson's (2005) prototypal development of a cognitive tool for enhancing problem solving performance. This cognitive tool improved learners' problem solving performance by allowing them to represent internal representations externally. Drawing upon the design theory of problem solving as the conceptual underpinning to their study, Russell and Schneiderheinze (2005) successfully fostered instructional reform and innovation in k-12 classrooms by developing constructivist-oriented learning environments. This was attempted through the design and implementation of an online workspace

for collaboration and problem solving meant to boost students' high-order cognition.

The dimensions of problem solving have been explicated in the design theory of problem solving in relation to the characteristics of a task-specific typology of problems for supporting problem based learning. Problems can be differentiated by their attributes and goals and this requires problem solvers to discriminate in the use of appropriate skills and dispositions to engage in problem solving. Generally, problems vary in terms of their degree of structuredness.

Structuredness

Problems vary in their nature, in the ways they are represented, in their components and their inter-relatedness. Problems could generally be categorized as being either ill-defined, non-routine and ill-structured or well-defined, routine and well-structured (Mayer & Wittrock, 1996; Jonassen, 1997).

Structuredness looks at the definitiveness of the problem space enveloping the problem and the degrees of clarity in the presentation of the problem elements. Well-structured problems require the application of a limited number of organized rules, theories, concepts and principles to a bounded problem in predictive and prescriptive ways. Well-structured problems consist of a well-defined initial state (what is known), a known goal state (nature of the solution well defined) and a constrained set of logical operators (known procedure for solving) (Jonassen, 2000). Problem criteria are explicitly stated in the problem statement, making the problem a static one.

Well-structured problems also have knowable, comprehensible solutions where the relationship between decision choices and all problem states is known or probabilistic (Wood, 1983). This leads to problem solving processes that tend to be preferred or prescribed in systematically working towards deriving the correct answers of the well-structured problems. Such well-structured problems are commonly encountered in schools and universities – typically found at the end of textbook chapters and during examinations.

On the other hand, ill-structured problems are the kinds of open-ended, emergent problems that are faced in daily, professional lives. Their solutions are neither predictable nor convergent. Not limited by the strict boundaries of content domains, these problems tend to be multi-disciplinary in character (Jonassen, 2000). Ill-structured problems possess problem elements that are not clear or not explicitly made known with any degree of confidence. These problems may not present all the information needed to solve the problems in their problem statements, resulting in the learner not easily identifying the rules, concepts and processes to be applied (Wood, 1983). Ill-structured problems have multiple solutions and solution pathways (Kitchner, 1983). Solutions are difficult to evaluate as the goals are vague. Solutions for ill-structured problems need to be constructed from students' personal judgments and decisions: What is the goal? What concepts are to be used to solve the problems? How can I get the solution and does it meet my goal? Hence, students learn to express their own opinions or beliefs about the problem, allowing ill-structured problem solving to be inherently inter-personal in character (Meacham & Emont, 1989).

Examining well-structured and ill-structured problems is an active area of research in education. In one study, researchers aimed to understand the factors that predict success in well- and ill structured problem solving ability (Shin, Jonassen & McGee, 2003). Results showed that both well- and ill-structured problem solving ability was dependent upon an integrated and organized knowledge base. In addition, ill-structured problem solving was also found to be dependent upon personal experiences related to the context of the problem. Another study (Brabeck & Wood, 1990) wanted to determine if ill-structured problem solving ability was dependent upon well-structured problem solving ability. Results showed that students can continue to develop their ill-structured problem solving capabilities without undergoing changes in their ability to solve well-structured problems. Dunkle, Schraw and Bendixen (1995) concluded that performance in solving well-structured problem tasks requires a different set of cognitive skills, analytic dispositions and processing operations in comparison to ill-defined problems. Competencies in solving well-structured problems cannot be readily transferred to ill-structured problems since they engage a different set of epistemic beliefs and metacognitive skills.

Having looked at how problems can be differentiated in terms of structuredness of the problem tasks, the next section examines how problem representations can be classified according to structuredness of specific problem types. Such a categorization helps in identifying and selecting appropriate problem solving strategies and processes to solve given problems.

Typology of problems

Jonassen (2000) suggested the following taxonomic typology of 11 problems from well-structured to ill-structured problems. These problem categories are neither mutually exclusive nor discrete since there are similarities and overlaps among the classes. In addition, the true nature of a problem is dependent upon the problem solver's prior learning experiences and approach towards understanding the problem. The different classifications of problem types include (a) logical, (b) algorithmic, (c) story, (d) rule-using, (e) decision making, (f) troubleshooting, (g) diagnosis-solution, (h) strategic performance, (i) case analysis, (j) design and (k) dilemma. Within each problem type, problems could vary in abstractness and complexity.

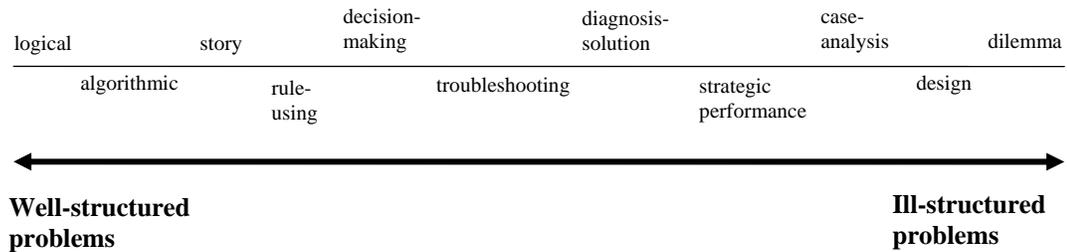


Figure 1: Schematic diagram of problem typology

- Logical Problems – abstract tests of reasoning that are used to assess mental acuity, clarity and logical reasoning. There is a specific and efficient method of reasoning that will yield the solution. Few logical problems are embedded within an authentic context, making the learning less transferable (Jonassen, 2000). Generally logical solutions yield single solutions. Morris and Sloutsky (2002) found in their study

that solving logical problems required learners to determine the basis of the logical form and necessity of the problems.

- Algorithmic Problems – problems that are frequently encountered in schools and are commonly found in mathematics and science courses. Examples include learning to perform long division, using a rigid and procedural set of actions with predictive and identifiable outcomes. Most of the solutions could be correctly assessed as being either right or wrong answers. Solving algorithms require number comprehension, number production and calculation. Learners' number processing skills, comprising of comprehending and producing numbers, aid the calculation procedures (McCloskey, Caramaza & Basili, 1985). The primary limitation of algorithmic approaches is their procedure-oriented nature of acquiring knowledge where the conceptual understanding of the underlying rationale and processes in engaging with the objects of the algorithm is rarely focused upon. One of the main conclusions of Chiu's (2001) research was indeed that students significantly did better in solving algorithmic problems than in understanding conceptual questions. Many students who were good algorithmic problem solvers were found to be poor conceptual thinkers.
- Story Problems – algorithms situated in some kind of context can often be found in mathematics education. Mathematical values are embedded within a narrative story and learners need to identify key words, select appropriate sequences and apply them accordingly to derive solutions. This is a more complex cognitive process of problem

solving when compared to solving algorithms (Sherrill, 1983). Solving story problems is often difficult because it requires reading comprehension and mathematics skills, capacity to visualize the data as well as the ability to transform words and numbers into the appropriate operation. Research suggests that difficulties with discriminating the correct operation, the order of operation (when placement of the unknown within the problem differs), and problems with computational speed are factors commonly associated with poor performance in solving story problems (Zentall & Ferkis, 1993; Lucangelli, Tressold & Cendron, 1998). Instructional strategies that can be leveraged upon in guiding students in tackling story problems include the use of manipulatives (concrete building blocks), cue cards and/or checklists outlining problem-solving steps and translating problem statements equation forms using illustrative diagrams (Marsh & Cooke, 1996; Cassel & Reid, 1996; Jitendra & Hoff, 1996).

- Rule-using Problems – problems with correct solutions but multiple solution paths or multiple rules governing the process. These problems usually have definitive purposes or goals that are constrained, though the strategies and methods to be applied in solving the problems are less restrictive. Simple rule-based problems include expanding a recipe to accommodate more guests and complex ones include completing tax returns (Jonassen, 2000).
- Decision-Making Problems – problems that involve selecting a single option from a set of alternatives based on a set of criteria. Making a

- Troubleshooting Problems – common problems with their primary purpose being fault state diagnosis. Some parts or parts of a system are not functioning properly, resulting in a set of symptoms that have to be diagnosed and matched with the user’s knowledge of various fault states. Analysing the symptoms, troubleshooters generate hypotheses to be iteratively tested and refined predicated on data collection and processing. Troubleshooting skills require systemic knowledge (how the system works), procedural knowledge (how to perform problem solving procedures and test activities), strategic knowledge (what are the strategies to be leveraged upon), functional and declarative knowledge (what are the system components and interactions, flow control, fault

states, fault characteristics and fault testing procedures) (Pokorny, Hall, Gallaway & Dibble, 1996). These skills are gained by organizing and integrating the troubleshooter's experiences in their mental models.

Johnson (1988) notes that the primary differences between expert and novice troubleshooters are the amount and organization of system knowledge. Some of the effective ways of teaching troubleshooting skills are through the use of functional flow diagrams (Johnson and Satchwell, 1993) and expert modeling (Hall, Gott & Pokomy, 1995).

- Strategic Performance – problems involving real-time, complex and integrated activity structures where the performers use a number of tactics to tackle more complex and ill-structured scenarios while maintaining situational awareness. Skills important in strategic performance include adaptively making real-time decisions, contextually improvising or modifying tactics in alignment with environmental changes, meeting cognitive demands in maintaining situational awareness, the ability to plan for, execute and concentrate on the dynamics of the situational specifics. Strategic performances can be complex undertakings (Durso & Gronlund, 1999). Hamilton (2003) in her research study established that organizational strategic performance is optimized when a firm during decision making recognizes the importance of accommodating context-specific ways of knowing and transfers the tacit knowledge of diverse identity groups within the organization into feasible strategies.

- Case-Analysis Problems – problems that are complex situated and require analysis of cases to prepare briefs and defend judgments. Cases are designed to simulate real life situations and allow learners to develop higher order practical skills. In these ill-structured problems, goals are vaguely defined with little being known about how to solve the problem, no consensual agreement being easily attainable on what constitutes a good solution and information available being incomplete, ambiguous or tacit. Compounding further is the lack of formal procedures or guidelines to inform the case analysis or govern the evaluation of solutions (Voss, Wolfe, Lawrence & Engle, 1991; Wagner, 1991). Case analysis is highly contextual and involves the following spiral of activities: goal elaborating, information collecting, hypotheses forming, forecasting end effects, decisive planning, monitoring the ramifications of one's actions and self-reflections (Dorner & Wearing, 1995). Analysing cases is clearly a complex process with complex outcomes. Easton and Ormerod (2001) observed that experts generated more alternative recommendations, identified more critical issues and used more evaluative criteria than novices.
- Design Problems – problems with ambiguous specification of goals, no determined solution path and the need to integrate multiple knowledge domains (Simon, 1973). Design problems can be characterized as the most complex and ill-structured problems. Due to the deep ill-structured nature of design problems, they require the problem solver to engage in extensive problem structuring and greater commitment and self-

- Dilemmas – the most ill-structured and unpredictable type of problems since often there is no single solution that is satisfying or acceptable to most people, and there are compromises implicit in every solution. Such dilemmas are encountered prevalently in everyday life situations, with the common dilemmas being social and ethical dilemmas (Jonassen, 2000). Dilemmas typically occur when there are conflicts between serving one's own personal self-interests and the collective good of a larger group of people (Schroeder, 1995). Resolving a dilemma is fraught with difficulties since there is no right answer and

there is no way of knowing in advance what the result will be of addressing a dilemma. This makes dilemmas provide rich and compelling contexts for active learning. By responding to the dilemma, a learner gains understanding and insight that makes constructive action possible. Tackling dilemmas require the solver to investigate the forces that are in tension or conflict. Exploring these points of tension leads to better understanding and increases readiness for action (Lowy, 2003).

Individual skills differences

In solving the different categories of problems suggested by Jonassen, individual skills-based differences mediate and affect success in problem solving. Some of the skills predictors that influence problem solving outcomes include domain and structural knowledge fluency, cognitive capabilities, metacognitive skills and affective dispositions.

Domain knowledge and skills of the solver are important determinants that impact upon problem solving performance. How much of domain-specific disciplinary content knowledge one possesses influences one's ability to comprehend the problem and generate appropriate solutions. However, this domain knowledge needs to be well-integrated in order to support problem solving and this integratedness of domain knowledge is termed as structural knowledge (Jonassen, Beissner & Yacci, 1993).

Structural knowledge refers to having a well-grounded understanding of how the constituent concepts within a specific domain are interrelated and organized within cognitive structures of relational relationships (Shavelson,

1972). Structural knowledge levels of learners have a strong influence on problem solving capabilities. Well-integrated domain specific knowledge is pivotal in problem solving. Robertson (1990) found in his study that structural knowledge is a strong predictor in physics problem solving success. Structural knowledge that conceptually links formulas and axioms in the knowledge base was noted to be important in understanding physics principles.

Cognitive styles and skills representing patterns of internal thinking control the ways in which individuals process and reason about information to perform problem solving (Jonassen & Grabowski, 1993). Learners with higher cognitive flexibility and competencies are better suited to be effective problem solvers since they are able to approach problems from alternative perspectives and tend to be more analytical in processing the problems (Stewin & Anderson, 1974).

Metacognition was described by Flavell (1979) as the awareness of how one learns, the ability to judge the difficulty of a task, the monitoring of understanding, the use of information to achieve a goal and the assessment of learning progress. Due to the considerable cognitive and affective demands of engagement in problem-based learning, the role of metacognition in problem solving is crucial (Jonassen, 2000). Problem solving requires the learner to be metacognitively aware of what information they already know about the problem, what information they need to know to solve the problem and the strategies to use to solve the problem. Being able to articulate such thoughts helps students become more effective problem-solvers and self-directed learners (Gijsselaers, 1996). In addition, metacognitive skills aid the solver to

deconstruct the problem into its elemental components, encode the problem by constructing a mental model of the problem space and its boundaries, select appropriate solution plans and identify obstacles to be overcome (Davidson & Sternberg, 1998). Orienting and self-judging are important metacognitive skills that are positively related to problem solving performance (Masui & DeCorte, 1999). Generally, metacognition and self-regulation in learning play a more significant role in solving ill-structured problems than well-structured problems.

Affective characteristics such as attitudes and beliefs about the problems, problem domain and learners' abilities to solve the problem directly affect problem solving performance. If problem solvers are inclined towards certain problem solution plans due to personal beliefs, this consequently reduces the effectiveness of exploring a myriad of probable comprehensive solutions to the problem and constrains them to pre-defined solution choices. Motivational factors such as developing in students their interest and confidence to engage in problem solving, empowering them to take ownership of their own learning and encouraging them to exert effort and strive to learn affect success in problem solving (MacKinnon, 1999). Effective problem solving requires a number of positive affective traits such as self-confidence, perseverance, task persistence and beliefs about the knowledge domain to want to invest sufficient cognitive efforts in their learning (Jonassen, 2000). According to Mayer's (1998) effort-based learning theory, students think harder and process information deeper when they are interested and believe they are capable enough in solving the given problem.

Some of the other generic skills that affect problem solving include problem solving abilities involving strategies. Using strong, domain specific strategies results in better performance in problem solving whereas applying weak strategies such as general heuristics like means-ends analysis does not markedly enhance effectiveness in problem solving (Mayer & Wittrock, 1996).

Information searching in problem solving

Existing literature has investigated the influence of different factors and skills such as argumentation abilities and representations (Alpay, Giboin & Dieng, 1998), scaffolding (Greening, 1998), impact of tutors (Jones, Donnelly, Nash, Young and Schwartz, 1993) on problem solving outcomes.

Argumentation reflects a person's ability to frame a claim in a coherent and persuasive way, providing supportable reasons for the claim as well as identifying the often implicit warrants (or assumptions) that underlie the claim. As a process, participating in argumentation helps a person to understand his or her own position more clearly in the light of counter claims or rebuttals made by others to be able to engage in problem solving. Interactions between scaffolding structures and students' use of scaffolding features contribute towards the development of metacognitive and higher order thinking skills in assisting students' enhancement of problem solving competencies. The pedagogical and content knowledge fluency of tutors in facilitating dialectical and knowledge transforming discourses with students is critical in underpinning the success of problem-based learning lessons. However, little research has been done on the influence of information literacy proficiencies

of students as a valid predictor of problem solving performance. Information literacy of students fundamentally encompasses the competency levels of students' information searching capabilities and the efficacy of information seeking strategies they choose to implement (Jones, 1998). Problem-solving learning activities are becoming increasingly prevalent in educational institutions and Internet-based information searching skills definitely play a critical role in enabling students to appropriate and apply useful information to solve given problems. For an information seeking action to be initiated in a problem solving task, the student first needs to recognize that there is a pertinent need to gather more information to better understand the scope and demands of the problem. Subsequent effective location and use of information to mould robust solutions is essential to problem solving and decision making (Zurkowski, 1974; Burchinall, 1976). Watson (2001) similarly argues that actively seeking new information from a variety of resources, integrating the new information with what is already known, organizing the new information in coherent ways through sound mental models and explaining the newly understood knowledge to others to validate its applicability are key skills that have to be developed in learners in order to successfully undertake problem solving.

Schaster, Chung and Dorr (1998) found in their studies that most students lack these important information searching skills and rarely employ systematic search strategies or select appropriate search terms. They also observed that students generally spend little or no time planning their searching. These findings further support the argument that Jonassen's list of

mediating skills impacting problem solving is not exhaustive and competent information searching literacy skills should also be included. The nature of the relationship between the effectiveness of diverse information searching skills and productiveness in problem solving is an important domain of educational research. Investigating the ways in which search strategies, techniques and approaches impact problem solving processes, as hoped for in this study, is indeed an area of potentially rich research opportunities. Jakes, Pennington and Knodle (2002) support this line of inquiry with their assertion that unless students are trained in all the necessary process skills to be able to operate as independent learners, it will be difficult for them to manage the complexities of problem-based learning. They further posit that meaningful implementation of a pedagogical approach based upon modalities of problem solving is directly tied to students' effective use of the Internet for acquisition of needed information. This is due to the fact that timely information retrieval and use are critical factors in ensuring success in problem solving and the Internet is undoubtedly the largest digital information repository hosting information that is immediately and easily accessible. Morris and Brading (2007) caution that those who are not comfortable enough in locating and using the wide array of educational resources available in the information rich Internet might become disenfranchised in their learning.

Defining Information Literacy

There are a broad range of popular definitions of information literacy and explanations of the attributes *expected of* in an information literate person. Information literacy generally embodies information searching and assimilation

(Mosley, 1998). Information searching refers to the ability to navigate through an information space, locate and retrieve relevant information resources through systematic investigation; employ thoughtful study and rational reflection on the information found and apply the information in useful contexts (Stern, 2002).

Many experts (Jackson, 1989; Murdock, 1995; Spitzer, Eisenburg & Lowe, 1998) have attempted to define the term *information literacy*, though Doyle's (1994) definition is the most succinct. Doyle describes information literacy as the ability to access and use information from a variety of sources in meaningful ways. However, other researchers have disagreed with such a simplistic characterization of information literacy since from early times of its conceptualization, information literacy has been recognized to be complex and multi-faceted (Bawden, 2001). True information literacy is multi-faceted in that as a discipline it calls upon the combination of a rich variety of skills and knowledge (Taylor, 1986; McClure, 1994).

Flashpolier (2003) found that students who had been explicitly taught information literacy scored better on information literacy skills tests, more often used resources to retrieve information, and more readily found appropriate informational sources for their projects. Reed, Kinder and Farnum (2007) examined and concluded in their study that planned collaborative efforts between librarians, students and teaching faculty can lead to strong success outcomes in improving the information literacy skills of students.

Attributes of an information literate person

Having understood the theoretical definitions of the term *information literacy*, it is important next to examine how the concept of information literacy can be crystallized and operationalized within applied contexts. From a pragmatic perspective, many experts (ALA/ACLR, 2000; Doyle, 1992; Bruce, 1994; Rader, 1991) have proffered detailed standards of the characteristics of an information literate person. These traits have been presented in the form of the following matrix for easy reference. An entry in a cell marked with a 'x' indicates characteristics that have been articulated by the authors in their standards. This table serves as a visual reference aid to locate commonalities as well as compare variations amongst the traits described in the standards.

Table 1: Attributes of an information literate person

	ALA/ACLR	Doyle	Bruce	Rader
Recognizes need & extent for information	X	X		
Formulates questions based on information need		X		
Identifies potential sources of information		X		
Develops successful search strategies		X		
Uses a variety of technologies & systems to search for information		X	X	X
Accesses needed information effectively & efficiently	X	X	X	
Integrates new information within existing knowledge base	X	X		
Use information for specific purposes through meaning-making e.g problem solving, decision making	X	X		X

Most of the standards emphasize the need for a successfully information literate person to be able to correctly read a situation that requires information and determine the extent to which information has to be acquired. The information literate person is able to efficiently draw relevant information from a variety of sources, notably those that are digitally formatted. Assessing the appropriateness and authenticity of found information, an information literate person is able to apply the information in multiple problem solving situations, both in local and global contexts, to improve his/her conceptual and structural understanding of the situation.

Some specific attributes mentioned in the individual standards, though not commonly found in all the standards, are nevertheless worth highlighting since they deepen our understanding of the notion of information literacy and its properties. For example, the ALA/ACLR (2000) standard makes an important call that the information literate person accesses and uses information ethically and legally. Bruce (1994) argues that an information expert citizen ought to engage in independent, self-directed learning and possess internalized values that promote information use. Such an individual also has a sound knowledge of the world of information and a personal information style that facilitates his or her interaction with the world of information. Martin (2006) stresses the need for information literate individuals to develop an understanding of the nature and contexts of digital environments such as the Internet in order to operate effectively within them.

The Internet – A vital informational and educational medium

The Internet has emerged as the most vital and powerful digital information medium in shaping and defining the educational field. Monoreo, Fuentes and Sanchez (2000) have explicated the following attributes of the Internet that distinguishes it as an important source of electronic information:

- 1) The Internet is a pluralistic, heterogeneous channel in which different means of electronic information production, publishing and diffusion interact.
- 2) The Internet allows for an exponential proliferation of information in multiple formats.
- 3) The information in the Internet can be changed and updated dynamically.
- 4) Locating and evaluating this information often requires a degree of specialization.
- 5) The information has not been systematically organized and there exists at times bias in favour of certain subjects to the detriment of others.

The Internet and the World Wide Web

The Internet is a technological tool with great potential to alter traditional classroom teaching and learning transactional dynamics. This is due to the plethora of educational and information resources that it offers for teachers and students. These resources can be accessed flexibly and on demand. The capacity to form connections between different sources of information, and thereby create useful information patterns, is required to learn

in our knowledge economy (Siemans, 2004). The advent of the World Wide Web in 1989 enhanced the Internet's affordability as a powerful technological medium that could be tapped to inject innovation into teaching practices to create more authentic learning experiences for students. Until 1989 information resources in the Internet had been disorganized and accessible only to a few individuals with fairly advanced technical skills (Grabe & Grabe, 2000). The World Wide Web infused much needed flexibility and user-friendliness into the Internet. It afforded the development of a networked hypermedia system based upon a hypertext model of interaction, emphasising a search-and-browse method of access of information (Chang, 2003). It should be reiterated that though the terms *Internet* and the *World Wide Web* or simply the *web* have been interchangeably used in vernacular and in this study as well, in actual fact, the two terms are not synonymous. They are two separate but closely related terms.

The Internet is an extensive system of interlinked yet independent computer networks connecting millions of computers together globally (Jonassen, Howland, Moore & Marra, 2004; McGuire, Stillborne, McAdams & Hyatt, 2002). This worldwide network of networks consists of a set of rules that allows computers to connect and communicate with other computers as long as they are connected to the Internet. On the other hand, the World Wide Web, or the web as it is commonly known, is the vast collection of text, graphics, sound and video files stored using a multimedia format (hypertext transfer protocol, or http). The web is an information-sharing model that runs on top of the Internet, allowing users easy access to the large number of

documents stored in Internet computers. The web browser is the graphical interface software that serves as the window to view and display the materials found on the World Wide Web by pointing the cursor and clicking the mouse button (McGuire, Stillborne, McAdams & Hyatt, 2002; Schlein, 2003).

Educational tools provided by the Internet

Warschauer (2000) found in his ethnographic studies that the Internet serves as a valuable educational resource. It provides educational tools for inquiry, communication and construction.

Tools for inquiry. In providing tools for inquiry, the Internet facilitates finding sources of information appropriate to a task, working to understand the information resources and how they relate to the task, and applying this understanding in an appropriately, productive way (Grabe & Grabe, 2000). By facilitating students' access to resources from the outside world, including experts in the field and direct collaboration with them, the Internet enhances students' knowledge construction. Thus, exposure to real life contexts trains students to face the uncertainties of the ever-changing outside world (Labbo, Reinking & McKenna, 1998; Michaelson, 2003). Otherwise, students who are not competent in using the Internet might end up being insufficiently armed with necessary skills to function effectively in the workforces they will face when they graduate (Leu, 2002). It is vital that students be trained to become proficient users of the Internet.

Tools for communication. The Internet has brought about dramatic changes in the way that we communicate. The use of electronic mail is the most obvious way our communicative behaviour has changed over the last

two decades. Instant messaging systems have also gained popularity with the integration of the Internet into various wireless devices such as portable telephones (Cziko & Park, 2003). Other Internet mediated synchronous and asynchronous communication include mailing lists, newsgroups, chat and videoconferencing tools (Grabe & Grabe, 2000). The increasing use of web-based technologies for achieving higher levels of learning has been well documented (Saunders & Cooper, 2003). For example, projects that made use of synchronous audio and video to link second language learners with native speakers reported a good measure of success (Belz, 2002; Blake 2000; Toyoda & Harrison, 2002). Some of the reasons cited for the widespread use of Internet communication tools include effective removal of geographical and situational learning barriers, provision of opportunities for increased interaction between instructors and learners, and improvement of quality of learning experiences (Garrison & Anderson, 2003).

Tools for construction. Constructivists argue that students have to be engaged in authentic tasks with real contexts for effective learning to take place (Means, 1994). In providing tools for construction, the Internet promotes constructivism in learning by scaffolding varieties of authentic learning activities for students (Michaelson, 2003; Dede, 1996). Through these activities the Internet also supports the development of higher-order cognitive skills such as transfer and knowledge application (Jacobson & Spiro, 1995). For example, students are able to demonstrate their conceptual understanding by constructing products such as web pages. Grabowski and Curtis (1991) highlighted that the Internet presents integrated displays of information in

different formats facilitating rich opportunities for self-guided, open-ended and interactive learning with little or no instructional guidance. This allows learners to regulate their individual learning progress according to their own experiences and expertise. Learners can at their own pace access the wealth of resources and have meaningful interactions with the content information to construct their own knowledge (Wilson & Lowry, 2000; Chang, 2003).

Skills and foundational knowledge essential for the effective use of the Internet

In the knowledge based economies of today, meaningfully searching for and retrieving information from the Web is critical. Skills essential to effectively finding information on the Web have become indispensable (Monereo, Fuentes & Sanches, 2000). Locating appropriate information on the Internet requires a variety of skills, such as the ability to use Internet tools, knowledge of search techniques, cognitive capacity to organize a search, and ability to execute the search (Carroll, 1999). Effective use of the Internet to glean relevant information requires the ability to apply Boolean logic rules and an understanding of how information is organized - critical thinking skills that allow the searcher to make informed choices and acquire a working knowledge of Internet functions.

Other necessary skills involved are general knowledge about the subject of the search, specific prior knowledge of the topics being scrutinized, narrowing and expanding topics, appropriating certain language capabilities and recognizing usefulness of information (Nachiamas & Gilad, 2002; Eagleton & Guinee, 2002; Eagleton, Guinee & Langlais, 2003). Mariani (2000) advocated that Web navigation entails integration of cognitive abilities such as

searching for information, scanning and skimming information and metacognitive strategies such as planning, monitoring and evaluating.

Besides these generic skills, Allen (1991) had, in addition, proposed four types of prior knowledge affecting the interaction of users with information systems such as the Internet: (a) world knowledge - general knowledge that might affect the information searching (b) system knowledge - the knowledge users have about the system they are using (c) task knowledge – users' ability to carry out a search task (d) domain knowledge - the knowledge users have about the topic being searched.

Internet Information searching tools

Students can locate informational resources on the Web by either going directly to a target website, if known or using a search tool (Eagleton & Guinee, 2002). To facilitate the process of searching for information in the Internet, the Internet itself offers various search tools and applications to help us in our search endeavours. Directories, search engines and metasearch engines are some of the common Internet search tools (Monereo, Fuentes & Sanchez, 2000)

Search engines and directories. Search engines and directories are the most ubiquitous tools that have been used to search for information in the Internet. Search engines and directories are both databases of web sites but they are constructed differently. A search engine is an enormous database of web sites compiled by a software program called a robot (alternatively also called a crawler, spider or worm) that seeks out and indexes web sites. At regular and frequent intervals the robot goes out to the web to search for new

or updated information content in the various websites it monitors. New data found is relayed back to the search engine's data center and included into the search engine's indexed database. Several search engines have emerged varying in speed, skill, depth of indexing, size of database, advanced search features and presentation of results (Jonassen, Howland, Moore & Marra, 2004). Major search engines regularly undergo changes on a periodic basis to suit individual search requirements. Google, Yahoo, AltaVista, Lycos, Infoseek and Excite are some of the common search engines on the web. Lawrence and Giles (1999) found in their study that many major search engines examined for coverage had minimal overlap of URLs in their return of results for each search query. Therefore, they recommended combining the results of multiple search engines to improve the coverage of web searches. By consciously training students to be aware of the strengths, limitations and situation-specific utility of different search engines, students can take better advantage of these search engines in accessing online information (Eagleton & Guinee, 2002). For example, Google finds relevant sites fast, offers a unique blend of best features and presents results in an easy to read format. WebCrawler allows for natural language to communicate their search question or topic to the search engine. Webcrawler is another good search engine with powerful advanced search features such as adjacency searching. However, WebCrawler has the smallest database index compared to other major search engines. This means that WebCrawler is not the place to go when seeking rare or difficult to find resource materials. On the other hand, Lycos is a popular search engine that has a large database of indexes, is user-friendly

and returns search results quickly. However, Lycos does not support Boolean searching or any other sophisticated searches like WebCrawler or Google. Alta Vista is yet another search engine that has one of the largest indexes, returns consistently reliable information and facilitates refinement of searches in more sophisticated ways than other search engines. Excite has more personalization features and allows users to select the way they prefer results to be presented on screen. However, its main drawbacks are that it offers only a medium-size database of indexes and its advanced features are complicated to use (McGuire, Stillborne, McAdams and Hyatt, 2002).

Search directories such as the one that can be found in Yahoo! are databases that use hierarchical structures. These structures are familiar to most people since the groups are built by categories, similar to subject sections found in a bookstore. Directories are an easy place to look for information on the web since people review the sites on them and group the sites into appropriate categories (Jonassen, Howland, Moore & Marra, 2004; Ackerman & Hartman, 2003).

Search engines are the preferred tools when one is looking for very specific information whereas directories are useful when one wants to know more information on broad-based subjects such as general and popular topics. When one's search is carefully thought out with awareness of the exact term to be searched for, search engines serve best in locating relevant information. However, if one is unsure of the precise search term to use and wishes to avoid the overwhelming number of hits a search engine might return, then browsing directories will be more helpful in suggesting keywords and

resources on the subject since directories tend to be better organized and selective. Though directories are much more focused and have higher quality links, they are usually smaller than search engines and thus, less effective when conducting exhaustive searches (Schlein, 2003; Ackerman & Hartman, 2003).

Meta search engines. A meta or multi search engine is one that searches across multiple search engines displaying records on the screen in any one of the different formats (Bradley, 2002). Meta search engines are valuable because they provide a quick overview of what may be available on the web and make comparisons between the search results of the different search engines (Schlein, 2003). However, integration through cross-referencing from multiple search engines doesn't necessarily mean that meta-search engines are faster or more productive than regular, general purpose search engines. Results from meta-search engines are less precise since all regular search engines use arbitrary limitations on the number of results that are to be displayed and the acceptable length of time with no results. Meta-search engines also use only basic search procedures. They do not allow refinement of searches and do not have many of the advanced search services offered by individual search engines to handle complex searches (McGuire, Stillborne, McAdams & Hyatt, 2002). During the intervention phase of this research study, students were familiarized with the features and functionalities of a variety of directories, search engines and metasearch engines so as to better understand how these search tools can be utilized to serve their information needs.

Limitations and constraints in learning with the Internet

Although the Internet offers a myriad of informational tools and pedagogical benefits, there are also a number of caveats that educators need to address in their attempts at employing the Internet as an instructional aid. Herring (2001) found from his study that students generally go straight to the Web without waiting for guidance from their teachers. This results in students having a difficult time navigating the Web and locating appropriate information relevant to the assigned tasks (Ebersole, 2000).

No one person can be expected to possess all the necessary fundamental skills to become effective Internet information seekers. These skills are complex and sophisticated for students to independently learn on their own (Gruwel, Wopereis and Vermetten, 2005). Students were generally found to be lacking in the proper knowledge of these fundamental skills and Web search capabilities. Hence, Web interactions can often be frustrating and confusing for these learners (Spink, 2003).

The problem is further compounded when students place blind faith in the legitimacy of the Web sites they visit and extract information from (Vansickle, 2002). These students may not be able to differentiate between websites that are authentic and those that contain biased and inaccurate information masquerading as being reliable. Schools are thus faced with the challenge of teaching students not just the power of having a wealth of information at one's fingertips but also the need to improve their ability to choose reliable information sources (Vansickle, 2002).

Time is one barrier to the extensive use of the Internet as students may be unable to spend a specific block of time on the Internet due to limitations in availability of computers with Internet access in schools. Another problem is access - some teachers are reluctant to give Internet-based learning tasks for fear that some students may not have Internet connections outside of school (Demirbilek, Tozoglu & Varavk, 2001).

These studies show that despite the Internet offering a myriad of pedagogical opportunities, mere use of the Internet alone will not automatically guarantee improved learning outcomes. Educators need to invest in proper instructional planning and design to foster stimulating learning experiences for students. Students themselves have to be systematically trained to understand the strategies and techniques of effective information searching to better harness the educational and problem solving affordances of the Internet.

Internet information searching techniques and strategies

Successfully searching for information: Cognitive techniques

Pejtersen and Fidel (1998) suggested a comprehensive framework of five different mental/cognitive techniques that could be employed in conducting information searches: Browsing, Analytical Strategy, Empirical Strategy, Known Site Strategy and Similarity Strategy. They explored the cognitive steps taken at a planning level to map out a searcher's search strategy. They found that the choice of cognitive technique students adopt in planning their searches for information found in the Internet is determined by time, intellectual effort, social interaction, and availability of information.

Browsing. This technique involves intuitive scanning and following leads by association without much planning. A large area of information is scanned without depth followed by browsing through a path until the desired goal is attained (Canter, Rivers & Storrs, 1985). Browsing is largely supported by the use of landmarks or home bases to which students frequently return back to continue their searches. Usually browsing is by nature heuristic, informal, continuous and opportunistic (Marchionini, 1989). Browsing can generally be micro-broken down into the following three types (Marchionini, 1995):

- 1) Directed browsing where browsing is systematic, focused and targeted at a specific goal. Examples of such types of browsing include scanning a list for a known item, and ascertaining content information.
- 2) Semi-directed browsing where browsing is generally purposeful and more random with the target being less definitive. Cove and Walsh (1998) argued that during such general purpose browsing, the user consults a generic range of sources to locate items of interest: An example of such a type of browsing is entering a single, general term to casually examine the retrieved information.
- 3) Undirected browsing where there is no purposeful goal or focus. Undirected browsing is serendipitous with the browsing being purely random and unstructured (Cove and Walsh, 1998).

Analytical strategy. Analytical strategies involve explicit consideration of attributes of the information need and of knowledge domain. This includes expanding the search scope with variations in the search terms being entered to elicit more fruitful results (Pejtersen & Fidel, 1998). Analytical strategies are

largely planned, goal driven, deterministic, formal and discrete in character (Marchionini, 1989).

Empirical strategy. Based on previous successful search experiences, students use similar rules or heuristics to embark on new searches.

Known site strategy. Based on an understanding of the structure of an URL which the students would have been provided earlier in the course of their previous assignments, students enter the same URL to retrieve the site and seek necessary information.

Similarity strategy. Find information based on previous successful examples that are similar to the current information need.

Successfully searching for information: Search strategies

The term *search strategy* adapted from Bates (1979) can be defined as consisting of a series of concrete actions (steps) aimed at finding information. Nachiamas and Gilad (2002) have explicated a taxonomy of three different information search strategies: search engine strategies, browsing strategies and direct access strategy. Their model deals with specific steps and actions taken at a procedural level when a searcher actually conducts the Internet information seeking activity.

Search engine strategies. The following are the six different types of search engine strategies:

- Keyword search – direct typing of the query subject
- Wide search definition – searching using a broad query
- Complex search – cross searching with more than one keyword

- Use of general knowledge – using information that is not mentioned in the search task
- Computer convention – use of computer codes
- Boolean search – using Boolean syntax.

They found that most students in their study employed search engine strategies and in particular, keyword searching to execute their information searches in the Internet while the other more complex strategies were rarely used. Similarly, Broch (2000) noted in her study middle and high school students' lack of sophistication in using search engines and the difficulties they encountered in locating information in the Internet.

Carter (1999) and Borgman (2001) have explored the use of search engine strategies and the difficulties students face in these attempts. Due to a poor understanding of how Web search engines function, students either ended up with huge amounts of irrelevant information or too few results. Zinns (2000) concluded that novice searchers often use “blind search” methods that yield one “big zero” or the stunning “success” of thousands of useless results. Such novices are weak in the processes of research and lack persistence and flexibility to be able to successfully explore and use digital resources (Neuman, 1999).

For better and more precise search outputs involving search engines, searchers need to exercise logical and cognitive reasoning in planning and conducting their information searches. Searchers also need to try multiple attempts at locating targeted information. Refining a search multiple times to narrow down lengthy search listings to meaningful ones is crucial. Such

refinement of search queries can be done in a number of ways including use of pull down menu options, full Boolean search strings and searching statements involving mathematical symbols such as addition and subtraction (Sullivan, 2001).

Browsing strategies. Browsing strategies consist of two techniques. The first one is what Nachiamas and Gilad (2002) called as 'using a directory' which means browsing through a directory or catalogue. Such an approach can be found in Yahoo! Website. The other option is to access a specific portal that is related to the subject of interest. This invariably requires preliminary knowledge of the subject being examined.

Direct access strategy. The final search strategy is direct typing where participants simply type the address of the known URL to access information of the topic to be explored (Nachiamas and Gilad, 2002). If the precise address is not known and one is familiar with top-level domain name endings, figuring out possible URLs and entering their addresses to search out for the relevant websites could potentially also be constructive (Notess, 1997).

The following table of Nachiamas and Gilad (2002) summarizes the various search strategies discussed earlier in this section. In their study they had administered to the students an online task of finding a picture of Mona Lisa.

Table 2: Taxonomy of search strategies

Strategy	Description	Example
Search engine strategies		
Keyword search	Direct typing of the query subject	Typing the words “ <i>Mona Lisa</i> ”
Wide search definition	Searching using a broad query	Searching for <i>art</i> and <i>painting</i> to find the Mona Lisa
Complex search	Cross searching with more than one keyword	“ <i>Picture</i> ”, “ <i>Mona Lisa</i> ”, “ <i>Louvre</i> ”
Use of general knowledge	Using information that is not mentioned in the search task	Searching for the Mona Lisa mentioning Leonardo Da Vinci
Computer convention	Using a computer convention	File suffixes (e.g .gif, .jpg)
Boolean search	Using Boolean syntax	Louvre and Mona Lisa
Browsing strategies		
Using a directory	Browsing through a directory or catalogue	Yahoo! Directory of topics
Accessing a specific portal	Looking for the subject of interest (requires preliminary knowledge)	www.artnews.com
Direct access strategy		
Direct typing	Simply type a URL	www.monalisa.com

Internet information search patterns

Having looked at the range of applicable Internet information searching techniques, procedural strategies and their associated effectiveness, next, the actual patterns of navigation exhibited by users during their information seeking attempts will be analysed. Such an analysis will enable better understanding of information search literacy as a function of successful problem solving by examining the strategies adopted and the navigational pathways charted by users in locating information websites.

Identified Internet information search patterns

Researchers such as Mariani (2000) have extensively studied and documented Internet information search patterns and behaviours. Based upon Gregorc's (1982) individual learning styles model, Mariani explained that there are two possible alternative styles of navigation in maneuvering through the complex information network of the Internet. The first approach is what he described as "structured, linear and sequential." In this mode, one embarks on a systematic and structured pathway of searching for and accessing information. The second approach, in contrast, is "less structured, non-linear and more random." One who uses this strategy explores the links that appear on screen to intuitively forge new ideas and relationships not planned beforehand.

Though Mariani's explanations provide a good overview of the two possible patterns of information navigation, they are simplistic as they do not sufficiently explain the rigours and complexities involved in navigational movements. Tauscher and Greenberg (1997) have expanded upon Mariani's work by establishing the following seven Web navigational patterns they observed from the analysis of the data corpus from their study:

- (1) first-time visits to a cluster of pages
- (2) revisits to pages
- (3) page authoring
- (4) regular use of web-based application

- (5) hub-and-spoke structures where there is navigation to each new page from a central page. Such structures are due to the frequent use of backtracking involving use of the “*Back*” common to exit to central page.
- (6) guided tours where links guide navigation through the web pages
- (7) in-depth-first searches where linked paths are followed but without returning to the first page at times.

Tauscher and Greenberg found that the majority of users adopted the fifth navigational pattern of “hub-and-spoke” style of navigation i.e., a navigational pattern involving frequent returns to certain home pages. The underpinning navigational moves involved following hyperlinks and using the back button. Cockburn and Greenberg (2000) attempted to rationalise this finding of frequent use of the back button by explaining that using this button has several cognitive advantages such as little need for decision-making since users need to repeatedly click “back” until the desired page is shown or until the start of the “back list” is reached or they give up. Another reason accounted for in the frequent use of the back button is its visual compactness since it consumes minimal screen space.

Measures to study network structures of information search patterns

Studies such as those referred to in the previous section employed static measures such as the number of accessed nodes or links, number of times particular web browser function buttons clicked or measures of time and path length to analyse attributes of search patterns (Qiu, 1994; Schroeder & Grabowski, 1995). Besides such limited static data analysis, a more dynamic

and spatial representation of web movements and navigational patterns can be realized through the use of navigational paths as data (McEneaney, 2001). The chief strength of path navigational analysis lies in the fact that a path is the most complete measure of user navigation and affords an important window in better understanding the search process and strategies users apply in acquiring information (Lawless & Kulikowich, 1996). Hence, this data analysis approach has been applied in framing the quantitative focus of this study to examine the patterns of navigation resulting from solving well and ill structured problems.

McEneaney (1999, 2001) has scrutinized the characteristics of students' navigational paths in two different ways. One form of analysis is based on graphical representations illustrating movements within networks of information nodes and visually documenting navigational patterns. The second form of analysis relies on path-specific structural metrics that are related to the graphical representations. McEneaney has constructed his model of analysis based upon closed-hypertext learning systems with definitive numbers of component nodes (web pages). This study has extended the application of his model to a more open-natured hypertext environment i.e. the Internet which in essence is made up of an infinite number of nodes and links.

McEneaney has developed his conceptual framework of path analysis based on the structural analysis of hypertexts originally developed by Botafogo, Rivlin and Shneiderman (1992). The two structural metrics he used to assess network-based navigational paths are compactness and stratum. These metrics are respectively the indicators of the complexity and

connectedness of network-based structures defining users' online navigational visitations. These metrics are also independent of the hypertext size. The constructs of complexity and connectedness provide good insights into some of the properties of users' online navigational movements.

Compactness refers to the overall connectedness of a network of nodes accessed, with more sparsely linked networks producing values for compactness close to 0, whilst densely connected networks yield compactness closer to 1. Thus, a high compactness value indicates a user navigational style involving easy movement from each node to other nodes within the network structure due to accessing a large number of cross referencing links. The following path diagrams taken from McEneaney (2001) show two very contrasting networks of navigation. Figure 2 is a completely disconnected network having a compactness value of 0 while Figure 3 reflects a completely connected network with a compactness value of 1.

Figure 2: A network with compactness value of 0

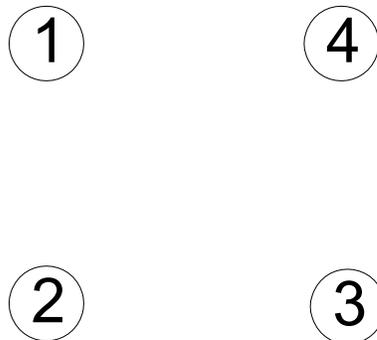
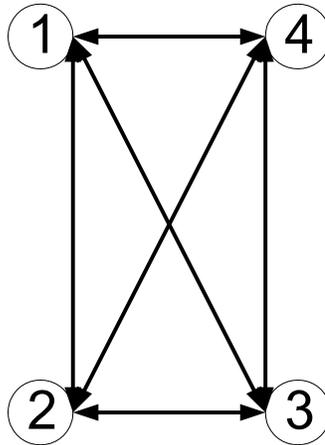


Figure 3: A network with compactness value of 1

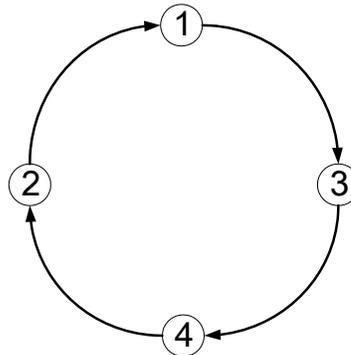


On the other hand, stratum indicates the degree of linearity of a network of nodes visited and it shows the extent to which a network is organized such that certain nodes are read before proceeding to others. Stratum also ranges between 0 and 1, with more linear networks and fewer cross-referencing links between the nodes having stratum values tending closer to 1 whilst more iterative, cyclic networks with a larger number of cross-referencing links having stratum values slanting towards 0. Thus, a high stratum value indicates that the user navigated in a predominantly linear, sequential fashion while traversing through the hypertext system. The following path diagrams again abstracted from McEneaney (2001) graphically illustrate two navigational networks with radically different stratum values. Figure 4 is a network that indicates highly linear, structured and sequential navigation with a stratum value of 1 whereas Figure 5 is a looping cyclic path having a stratum value of 0.

Figure 4: A network with a stratum value of 1



Figure 5: A network with a stratum value of 0



In this chapter on the review of literature to underpin the theoretical basis and rationale of the research design of this study it was highlighted that the Internet has be situated as an important pedagogical tool due to the vast amounts of easily accessible information it hosts. The critical role the Internet plays in the educational realm comes under scrutiny specifically in the context of problem

solving where learners need to seek out, interact with and use new information to successfully resolve given problems. However, problem solving activities are neither similar nor uniform since problems are embedded with different levels of cognitive complexity and structuredness. This literature review has discussed the broad spectrum of information searching techniques and strategies that could be leveraged upon by learners in scaffolding their information searching efforts. Possible quantitative measures of search navigational patterns were also looked at.

CHAPTER 3 – METHODS AND PROCEDURES

Purpose of the study

Problem-based learning is a pedagogical approach that facilitates students' active construction of knowledge through problem solving. Jonassen (2000) has broadly classified problems as being either well-structured or ill-structured. Inherent complexity and difficulty in the task design of the problems given to students can also be varied to bring students through a continuum of diverse learning experiences. Problem solving also requires students to become independent, self-directed learners who autonomously monitor their own learning progress and determine their desired learning outcomes.

A problem based learning system inherently requires learners to expertly seek out and locate relevant information from multiple sources in assisting them to formulate cogent solutions to problems. Electronic information media such as the Internet offer rich opportunities for students to locate and use information required for solving given problems. Developing necessary awareness, skills, understandings and approaches for a learner to operate comfortably in such technology-enabled, information rich environments is necessary for accomplishing problem solving (Martin and Ashworth 2004). In Singapore, schools and tertiary institutions have been well equipped with impressive technological infrastructures that enable extensive access to the Internet. Generally, Singapore students are encouraged to

acquire self-taught Internet information searching and navigation skills. It was found in a study on the information literacy practices of secondary school students in Singapore that these students were generally well acquainted with the interface and features of the Internet but lacked competent information search skills to be able to locate and use information to deepen their learning. These students were in want of further training in information literacy proficiencies (Muthukumar, 2005). Indeed, Gruwel, Wopereis & Vermetten (2005) cautioned that information seeking within a problem solving context can be characterized as complex cognitive skills. Students need to be systematically trained through planned curricular instructions to become fluent in these skills. In the absence of systematic, scaffolded training on effective information searching, students may be lulled into a false sense of complacency of their actual information literacy skills and end up spending an enormous amount of frustrating time trying to find desired information in the vast electronic landscape of the Internet.

Hence, one of the main goals of this study was to formulate and empirically test the efficacy of an interventionist conceptual model that maps the application of different information seeking techniques to successfully resolving well and ill structured problem types. This inquiry-based framework informs educators on the organized development of a repertoire of competent information seeking skills in students to improve their problem solving performance. It was hoped that a set of heuristics could be established in linking the efficacy of different Internet information searching strategies to the nature of structuredness of multi-disciplinary authentic problems.

The implementation and validation of the framework was done in relation to analytically examining the pedagogical structure of a problem-based learning curriculum implemented in a reform-minded tertiary institution in Singapore. Both, the structuredness and complexity of some of the problem-solving tasks that were assigned to students in the course of the one-day-one problem solving approach administered over the period of a semester were studied. The multi-faceted, heuristic ways in which students search for information and approach problem solving were also investigated.

Mixed methods design of the study and its rationale

A mixed methods research design (Creswell, 1994) involving an integrated approach that employs the highest degree of mixing of both qualitative and quantitative research protocols was adopted in this study. A mixed methods research design was chosen as it enabled eclectically combining aspects of qualitative and quantitative research approaches during the data collection, analysis and discussion phases. This harnessed the benefits of both qualitative and quantitative research paradigms. A mixed methods research design also allows for better corroboration and elaboration (Rossman & Wilson, 1985). Corroboration enables convergence of qualitative and quantitative approaches and helps to strengthen the validity of these findings. Elaboration provides additional details that may have been omitted if only one approach had been adopted. Thus, the overall design holistically incorporated both inductive and deductive models of thinking critical to effective research inquiry.

In qualitative studies, normally both theory and literature are employed inductively with an emergent design guiding the framing of the problem. On the other hand, in quantitative studies, theory and literature are used deductively to position the development of the research questions (Creswell, 1994). In the mixed methods design approach of this study, various modes of use of theory and literature were integrated, both inductively and deductively, without strict adherence to isolated interpretations of inductive and deductive perspectives. In the literature review section, both descriptive studies of the qualitative research traditions and empirical/experimental studies of the quantitative traditions were used to strategically focus on research issues related to the phenomena of Internet information searching and its impact upon problem solving processes. In advancing research questions and hypotheses for this study, descriptive, broad-based, exploratory research questions were posed in the language befitting the design characteristics of the qualitative research paradigm whilst hypotheses were formulated to quantitatively analyse measurable constructs and test relationships between variables, where appropriate. In the data collection phase, both qualitative and quantitative data was concurrently collected for analysis. Qualitative data included students' responses in their reflection journals, open-ended survey questionnaires and students' end-product artifacts. Quantitative data sources were the video screen captures of students' web movements. Data analysis involved using content analysis of qualitative data as well as statistical analysis of quantifiable measures. Hence, elements of both research approaches were married together vigorously at various stages of the study to

create an integrated, methodologically sound research design framework.

Research questions and hypotheses

In advancing research questions and hypotheses for this study, both emergent, qualitative research questions and specific quantitative research hypotheses were formulated. The descriptive, broad-based, exploratory research questions were posed in the language befitting the design characteristics of the qualitative research approach. These questions examined key issues such as the situated nature of problems, the differential information needs of these problems, students' perspectives on their problem-based learning experiences and the association between information searching behaviours and problem solving outcomes. On the other hand, the quantitative hypotheses tested the validity of predicted relationships between the constructs of connectedness and complexities of network-based information search structures and abilities to solve a typology of problems. These hypotheses attempted to gain valuable insights into the properties of the search movement trajectories of students whilst engaged in problem solving. Put together, the research hypotheses and questions mutually informed one another and were conceptually connected to enable us to improve our understanding of the relational association between information searching and problem solving. Seeking answers to the specified research hypotheses and questions in an integrated manner produced a final conceptual product that explained the nature of the functional relationship between different information search strategies and well-structured as well as ill-structured problem solving outcomes. Educators could then leverage upon

this knowledge to better assess information needs in designing problem-based instructions and mount necessary remediation training to raise students' information search literacy competencies.

Research questions

The following research questions were qualitatively investigated in this study:

- 1) How do students view the Internet as an information tool to approach problem solving? What are the primary strategies and techniques they adopt in using the Internet to search for information?
- 2) What are the structural attributes and design elements of well and ill structured problems? What are the differences in the ways students approach solving well and ill structured problems and the subsequent processes they employ in constructing solutions to these problems?
- 3) What is the nature of the relationship between different Internet information searching skills and students' performance in solving well and ill structured problems?

Research hypotheses

The following hypotheses were quantitatively analysed for their validity:

- 1) There is a significant difference between the path compactness metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.
- 2) There is a significant difference between the path stratum metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.

Rationale for hypotheses (1) and (2)

The two structural metrics of stratum and compactness that McEneaney (2001) advanced in his work were used in this research study to investigate the nature of the relationship between these metrics characterizing the structure of network-based navigational paths and students' performances in solving well and ill structured problems. Stratum and compactness are respectively indicators of the linearity and connectedness of network-based structures defining patterns of users' online navigational visitations. These metrics are independent of the hypertext size of the traversed networks. The measures of linearity and connectedness provide good insights into the properties of users' Internet navigational movements.

Students were expected to differentially traverse Web space in networks of navigational pathways to search for information in framing their online movements in response to the structuredness of the given problem task. Well and ill structured problem tasks have different cognitive, affective and information demands. Thus, the patterns of navigation to gather information to organize problem solving were postulated to be different for the two different types of problems. The information searching needs of well-structured problems are usually bounded since the domain content knowledge for solving well-structured problems tend to be from one or at most two disciplinary fields. Typically encompassing a limited number of well-linked elements and organized around prescriptive solution means, well-structured problems call upon a less comprehensive information seeking orientation.

On the other hand, ill structured problems are typically emergent, ambiguous and situated at the intersection of multiple content domains. Contextually embodied, having fewer prototypic precedent examples, containing multiple evaluation criteria and having no definitive solution pathways, ill-structured problems demand an expansive set of information searching skills and strategies to support problem solving. Students need to tactically seek out a wider and diffused base of multi-disciplinary information resources to enact problem solving. Synthesizing information within a unifying framework through interpretation and meaning making, students need to cognitively construct problem schemas and generate a myriad of testable solutions to tackle ill-structured problems. Thus, a more varied and substantive repertoire of information searching capabilities needs to be leveraged upon by students in deconstructing ill-structured problems.

For this study, it was postulated that students need to traverse Web space in networks of navigational pathways with lower values for the path compactness metric in successfully solving well-structured problems when compared to solving ill-structured problems. Conversely, the characteristics of the networks of information searching navigational movements for solving well-structured problems would reflect higher values for the path stratum metric compared to those for solving ill-structured problems.

The justification for this supposition was based upon the argument that for students to successfully solve well structured problems, students need to possess fundamental information searching skills and utilise a limited number of information searching strategies. This is due to the fact that well-structured

problems have known parameters with well-defined boundaries and require the operation of a finite set of regular logical procedures with correct, convergent answers. Thus, the information needs of well-structured problems are discipline specific and easily identifiable, with subsequent information searching activities being readily organized involving a limited number of resource websites. Students were thus expected to traverse in paths connected by embedded links in sequential fashion to display linearly ordered and less connected patterns of navigation.

On the other hand, students need to exercise higher levels of information literacy skills and utilize a wider catalogue of information search strategies to solve ill-structured problems. This is due to the fact that ill-structured problems require a larger fund of disciplinary skills, knowledge and perspectives from multiple fields of expertise. Hence, students were expected to show a more iterative and recursive style of navigation involving distributed access of a large number of websites and links within them. Such navigational patterns contribute to more connected and less linear networks. These networks then tend to have high values for path compactness metric and low values for path stratum metrics.

Research site, its PBL methodology and sample

The research site for this study was a polytechnic tertiary institution in Singapore. As a recently-established educational entity where premium is placed on innovative and stimulating teaching practices, this polytechnic has embraced pedagogical reforms by implementing a problem-based learning methodology for all curriculum subjects at an institution wide level. A

curriculum design model based upon a problem-based learning orientation was adopted in alignment with the principal goal of empowering students to be reflexive, self-regulated and autonomous learners. This model hoped to encourage a pervasive learning culture of problem solving that would serve as the catalyst in provoking students to embrace new ideas, question the validity of both their own and others' viewpoints, engage in meaning-making and consensus building.

Students work in teams of five on a given problem each day of the week for the different disciplinary subject modules. Students are required to come to classroom lessons with their laptops equipped with wireless connectivity to access the Internet for information searching and sharing. These laptops can be purchased at subsidized rates from the polytechnic's vendor partners. The unique one-day-one problem solving structure allows students to co-operatively construct new forms of knowledge by experimenting with and implementing a slew of adaptive problem solving strategies. Structured support from facilitators ensures that students are not left to flounder in this process. The assignment of members to each team is left to the discretion of each facilitator who conducts the class. Usually, team membership is periodically rotated so that each student would have collaborated with every other student in the class by the time the semester ends. Each problem carries a set of learning outcomes, a context for learning activities and exploration (articulated in the problem statement) and scope of assessment. The day is typically structured with three meetings that facilitate

interactions between facilitator and student groups on how best the problem can be approached and tackled.

During the first meeting at the beginning of the day, the problem statement is released to students and students within their team formations begin brainstorming the problem by filling up the columns of the first meeting template. The three columns in the first meeting template require students to enter in what they know, what they don't and what they need to find out in relation to the given problem. This first meeting template is an instructional support that scaffolds initial discussions and clarification of ideas when students in their teams encounter the problem. Filling up the columns of the template encourages a structured inquiry approach to problem solving by enabling the mapping out of an action plan that identifies the knowledge gap and applies new information to resolve the problem. During the second meeting which happens about 2 hours after the first, students gather back in class to have further group discussions on the problem in crystallizing their solution ideas and seeking necessary clarifications from the facilitator. At the third meeting which occurs after lunchtime, students in their groups are required to present their solutions to the entire class and be collectively prepared to defend their solutions with persuasive, logical arguments when critiqued by the facilitator and fellow students. Team presentations are assessed to inform students of their learning achievements and progress. At the end of the daily class, students have to post their individual entries in the online reflection journal in response to a reflective trigger question posed by

the facilitator. Reflection allows students to metacognitively think back on how they responsively and reflexively engaged in problem solving.

For the purpose of this study, the sample population of students came from a class of 25 first-year students for the module of 'cognitive processes and problem solving' that the researcher facilitates. The students in the class ranged in ages from 17 to 19 and were an even mix in terms of gender distribution. Though coming from different schools of disciplinary specialization such as applied sciences, engineering and information and communications technology, this module of 'cognitive processes and problem solving' is a common subject for all first year students and thus, brought the participant students together within the same class. Six problems from the curriculum of the 'cognitive processes and problem solving' module were selectively chosen – three being well-defined problems with the other three being divergent problems. These two clusters of problems represented the well-structured and ill-structured domains of the continuum of problem solving typologies specified by Jonassen (1997, 2000). The problem statements of these six problems which were given to students over the period of a semester have been included in the Appendix B section. The detailed description of these problem scenarios and the rationale behind their classification of being either well-structured or ill-structured has been presented in chapters four and six of this thesis dissertation. Students were randomly assigned to their initial groups and as per the polytechnic's current practices, group allocation of students was routinely changed for each problem tackled in this study. Regularly rotating students in their group formations afforded opportunities for wider

collaboration and greater learning and this naturalistic setting was retained for the purpose of this study.

Sources of data

Multiple sources of data were collected for analysis, both during the pre and post intervention phases as well as the period of progression of the proposed intervention. Some of the sources of research data collected included student authored solution artifacts such as powerpoint slides, inputs to the instructional scaffold of first-meeting template, concept maps constructed in response to the end-product output requirements of practice sessions and observation notes taken during students' presentations. One pre-intervention survey with open-ended question items was carefully designed and administered to students to solicit students' responses. This was valuable in probing in-depth students' mental schemas of understanding and the rationale behind their information searching actions. An open-ended items-based questionnaire supplies flexible frames of reference, thereby, facilitating richness and intensity in student responses with minimal restraint on their output expressions. Thus, a better assessment of students' attitudes, beliefs and knowledge levels could be ascertained. Students' contemplative feedback in the form of their electronic reflection journal entries was yet another rich source of data for analysis. Reflection journals serve multiple purposes such as encouraging the documentation of students' contemplations and enabling the facilitator to monitor the learning progress of students. Hence, students' entries in these reflection journals provided evidence in tracking students' progressive thought and intellectual developmental during the periods of active

engagement with problem solving. Finally, students' online movements while searching for information through the Web space of the Internet were captured using Camtesia screen capturing software to record full motion video of all screen movements. These screen recordings were then examined for hypotheses testing.

Data collection procedures

The data collection for this study was done in phases, as outlined in the diagrammatic representation Figure 6. These phases could broadly be broken down into problem solving episodes and Internet information searching skills training periods. The problem solving phases cover each of the six selected problems with related problem solving processes and approaches employed by students documented. Interspersed in-between these problem solving phases were the training interventionist phases where Internet information searching skills were systematically imparted to students. The discussion on the different components of the intervention framework, how it was implemented and the instructional impact of the provided training on students' problem solving abilities is presented in-depth in chapter 5. During each of the problem solving sessions for the six problems, students were randomly rotated in their team allocations. This was to ensure that factors such as students' familiarity with one another, their underlying epistemic beliefs and individual prior disciplinary content knowledge expertise that potentially could affect problem solving outcomes could largely be controlled for. The researcher who was the facilitator of the class of students taking part in this study played the role of a participant observer. Participant observation makes no prior

assumptions about what is important during the research investigations and encourages the researchers to immerse himself in the day-to-day learning activities of the students being studied. This approach was employed as it would allow the research to be actively involved in the natural environment of their classrooms and gain familiarity with their information searching and problem solving practices, behaviours and attitudes.

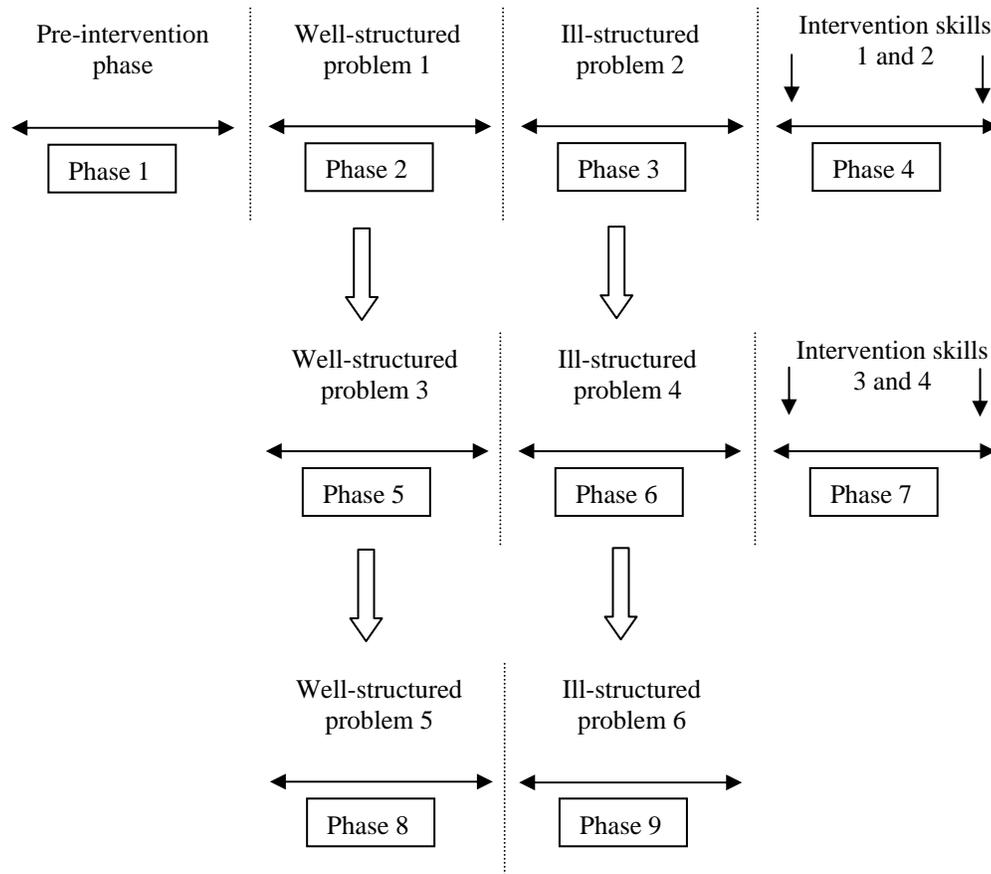


Figure 6: Schematic layout of data collection sequence

Phase 1

During this phase, which could be termed as the pre-intervention period, an open-ended survey questionnaire was administered to examine the Internet information search literacy practices and proficiencies of students. Analysis of the qualitative data from this survey enabled the researcher to determine the common search tools and techniques frequently used by students to carry out their information seeking activities.

Students' perceptions in response to the following reflection journal prompts were gathered:

- (1) What are your views on using the Internet as a learning tool to search for information?
- (2) What strategies or techniques do you use in conducting an information search in the Internet?

An in-depth analysis of students' feedback inputs for these trigger questions facilitated an informed assessment of student's views of the Internet as a pedagogical enabler and their pre-intervention levels of Internet information seeking competencies. Some of the misconceptions found in students' responses explaining how they perceived the Internet to be functioning and the utility of the Internet as an information medium were then taken up and addressed during the intervention training sessions.

Phases 2, 3, 5, 6, 8 and 9

These phases were the problem solving sessions for the six chosen well and ill structured problems for this study. During each of these phases, notes were made about how students explored problem solving through

consensually identifying learning issues, defining the conceptual boundaries of the problem, drawing out the main elements of the problem and constructing the problem space. Other issues that were observed included how students generated working ideas and hypotheses, reconciled conflicting perspectives and built up integrated solutions.

Students' collaborative team inputs to the instructional scaffold of first meeting template were collected for each of the six problem solving sessions. Analysis of this data allowed the researcher to better evaluate students' prior levels of domain knowledge competencies and the roadmaps students formulated in organizing their problem solving activities. Students had to demonstrate their learning achievement for the day by submitting their end-product artifacts representing their solutions to the problem. These artifacts, normally in the form of powerpoint slides and/or word documents were collected for analysis. They enabled the researcher to probe deeper into how adaptively students employed different problem-solving strategies in attending to ill and well structured problems as well as assess the viability of the presented solutions. Finally, students' cogitations in their reflection journals for each of the six problem solving sessions were collected for analysis. Students' contemplations were evaluated to review the suitability of the problem solving strategies they had employed and the closeness of fit between the goals of these strategies and the demands of the problem. This helped to shed light on the problem solving flow in the processes employed by students in moving recursively from grasping the parameters of the problem to generating and testing solution options.

For phases 8 and 9 alone, students' online movements while navigating through the Web space of the Internet in search of information to support problem solving were captured using Camtesia screen capturing software. Each of the students' notebooks was installed with Camtesia. This sophisticated piece of software expertly records full motion video of all screen movements. Camtesia served as a sort of digital video camera in chronicling students' online navigational activities. From the screen recordings, each distinct website accessed by students was numerically labeled and the sequence of visitations recorded. Screen movements capture data was only collected at phases 8 and 9 to ensure that the maturation of the impact of the training on information searching skills provided to students during the intervention phases of 4 and 7 was achieved before statistical analysis testing could reliably be carried out.

Phases 4 and 7

These two intervention training phases were sandwiched in-between the problem solving sessions so as to be able to compare the treatment effects of the intervention on students' overall problem solving performances. The pedagogical impact of the information searching skills training delivered during phases 4 and 7 were assessed by examining improvements or changes in students' problem solving characteristics, abilities and outcomes in relation to the structuredness of the problems. For phase 4, variations in students' approaches to problem solving between phases 2 and 5 for well-structured problems as well as phases 3 and 6 for ill-structured problems were looked at. For phase 7, differences in students' problem solving practices between

phases 5 and 8 for well-structured problems as well as phases 6 and 9 for ill-structured problems were analysed.

Each intervention phase consisted of workshops for students to participate in interactive instructional sessions where key concepts and principles associated with the particular stage of the intervention were explained through a combination of knowledge sharing, worked examples and guided practice. At the end of the practice sessions, students were instructed to submit the artifacts they had produced in response to the given task specifications as evidence of their learning progression. These artifacts were collected as they were important sources of data in analyzing how students applied the taught Internet information searching skills in problem solving and providing timely diagnostic feedback to apprise students of their learning performance.

Assessment of student-authored artifacts

The final product artifacts submitted by students in response to the given problems as evidence of their learning achievement were assessed according to qualitative criteria-based evaluation to determine the quality of students' problem solving performances. Based upon evaluation rubrics such as HSA rubric for constructed-response items, Florida Comprehensive Assessment Test (FCAT) scoring rubrics, Mathematics Scoring Rubric and MCPS Science rubrics, a total of six criteria items were framed for this assessment: knowledge/understanding, analysis, strategies and reasoning, relevance and accuracy of supporting details/evidence, synthesis and organization of information and communication of ideas.

Knowledge/understanding looked at the depth of interpretation students demonstrated in their comprehension of the problem through the use of representations and procedures accurately reflecting the important concepts embedded in the problem. Analysis dealt with how well students grasped the structure and context of the problem to be able to break the problem into its component parts and make coherent linkages between these conceptual parts. Strategies and reasoning scrutinized whether students proceeded from a plan, applied appropriate strategies and followed a logical and verifiable process towards a solution. Relevance and accuracy of supporting details/evidence examined to what extent students were able to present relevant and reliable information in the solutions they had generated. Synthesis and organization of information analyzed the comprehensiveness of the work done by students in effectively integrating and using information to address the task-specific requirements of the problem situation. Communication of ideas referred to how clearly and effectively students had communicated their ideas using creative and diverse presentation means and defended the validity of their solutions.

Data analysis procedures

Each of the nine phases was taken as the major unit of research analysis for this study.

Analysis of quantitative data

Inferential statistical analysis was used in testing the validity and strength of the formulated hypotheses 1 and 2. Paired samples t-tests were used in measuring the significance of the differences between the values of the variables specified in the hypotheses for this research study.

Testing for hypotheses 1 and 2 heavily drew upon McEneaney's (1999, 2001) path navigation parameters in computing the key path metrics of compactness and stratum. The first step in his model is to create a path matrix. A path matrix represents frequencies of node transitions during a browsing session from each node in the path to every other node in the path. It is constructed inclusive of each distinct node in the path that was visited with the appropriate cell incremented for each transition represented. Table 3 below illustrates with an example on how a path matrix was formulated from a path structure in a closed hypertext learning environment. Each of the nodes in the path matrix represents a unique web page within the hypertext system that was visited. Concurrently, the navigational paths of the students could also be graphically plotted in Microsoft Visio to display path diagrams in the form of node and link networks as shown in Figure 7. These visual representations were intended to better facilitate the structural analysis of the navigational patterns of students' online interactions.

Table 3: A path and its corresponding path matrix

Path = < 1, 7, 1, 9, 1, 2, 3, 1, 4, 1, 4, 7, 1, 5, 6, 1, 8, 1 >

To From	1	2	3	4	5	6	7	8	9
1	0	1	0	2	1	0	1	1	1
2	0	0	1	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	1	0	0
5	0	0	0	0	0	1	0	0	0
6	1	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0

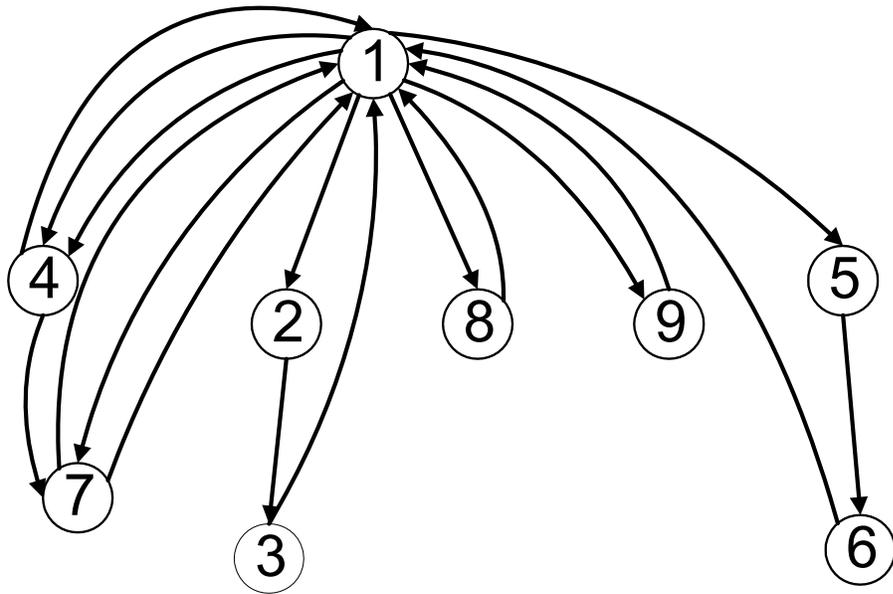


Figure7: Path diagram

The next step in McEneaney's data analysis approach is the creation of a distance matrix for the path based upon the concepts propounded by Botafogo, Rivlin and Shneiderman (1992) and Rivlin, Botafogo and

Shneiderman (1994). This is done by substituting a value of “1” for all entries in the original path matrix that exceed one. This indicates that these entries represent multiple transitions across a direct link between two nodes. Entry for a cell in the path distance matrix where no direct link of access existed from one node to another was calculated based upon the minimum number of steps taken to reach from the specific node to the other. An infinite value is inserted in a cell in the case where one node has not been accessed from another node. A converted distance matrix for the path is then finally created by replacing all cell entries with an infinite value (cases where one node has not been accessed from another node) except for the diagonal cells with the conversion constant, K where K is set to be equal to the number of distinct nodes in the path matrix. Table 4 shows the converted distance matrix for the path in Figure 6.

Table 4: Converted distance matrix for the path in Figure 7

To From	1	2	3	4	5	6	7	8	9
1	0	1	2	1	1	2	1	1	1
2	2	0	1	3	3	4	3	3	3
3	1	2	0	2	2	3	2	2	2
4	1	2	3	0	2	3	1	2	2
5	2	3	4	3	0	1	3	3	3
6	1	2	3	2	2	0	2	2	2
7	1	2	3	2	2	3	0	2	2
8	1	2	3	2	2	3	2	0	2
9	1	2	3	2	2	3	2	2	0

Using these structural path matrices, the two specialized path metrics of compactness and stratum used in the analysis of global properties of users' navigation paths can now be formally defined. Path compactness (P_{Cp}) refers

to the connectivity of a user's path based upon the notion of connectedness and is evaluated as

$$P_{Cp} = \frac{(P_{Max} - \sum_i \sum_j PC_{ij})}{(P_{Max} - P_{Min})}$$

where $\sum_i \sum_j PC_{ij}$ refers to the sum of the entries in the converted distance matrix for the path and P_{Max} and P_{Min} refer respectively to the maximum and minimum converted distance values.

P_{Max} and P_{Min} are calculated as

$$P_{Max} = K(n^2 - n) \quad \text{and} \quad P_{Min} = (n^2 - n)$$

where n is the order of the path matrix and is taken to be the number of unique web pages that were read and which therefore appear in the path. K is the conversion constant and is set to be equal to the total number of unique nodes (web pages) visited by the user. Thus the convention adopted in this study results in $K = n$. For the path represented in Figure 5, $K = n = 9$,

$$P_{Max} = 648, P_{Min} = 72 \text{ and } \sum_i \sum_j PC_{ij} = 153$$

Therefore the path compactness, P_{Cp} is calculated to be 0.86.

Path stratum (P_{st}) explains the degree of linearity of the path structure and is defined as

$$P_{St} = \frac{\text{Path absolute prestige}}{LAP}$$

where the path absolute prestige is a sum of the absolute values of finite prestige values for the distinct nodes that were traversed. Path absolute

prestige is the sum of absolute values of prestige. Prestige is status (calculated for each node by counting the number of nodes which are subordinate to it) minus contrastatus (calculated as the number of nodes which are superior to that node). Prestige of a node indicates the position of a specific node with respect to others in the path structure in terms of t. The linear absolute prestige (LAP) of a network with n unique nodes is meant to make the construct of stratum metric global and thus its values comparable across networks of varied sizes.

LAP is defined as follows:

$$LAP = \begin{cases} \frac{n^3}{4} & , \text{if } n \text{ is even.} \\ \frac{n^3 - n}{4} & , \text{if } n \text{ is odd.} \end{cases}$$

Again taking the example of the path mentioned in Figure 6, 'status', 'contrastatus' and 'prestige' values are calculated using the path's corresponding converted distance matrix from Table 4.

Table 5: Values of status, contrastatus and prestige

To From	1	2	3	4	5	6	7	8	9	Status	Prestige
1	0	1	2	1	1	2	1	1	1	10	0
2	2	0	1	3	3	4	3	3	3	22	6
3	1	2	0	2	2	3	2	2	2	16	-6
4	1	2	3	0	2	3	1	2	2	16	-1
5	2	3	4	3	0	1	3	3	3	22	6
6	1	2	3	2	2	0	2	2	2	16	-6
7	1	2	3	2	2	3	0	2	2	17	1
8	1	2	3	2	2	3	2	0	2	17	0
9	1	2	3	2	2	3	2	2	0	17	0
CStatus	10	16	22	17	16	22	16	17	17	153	26

For this path, path absolute prestige = 26 and $LAP = 180$. Hence the path stratum, P_{St} is found to be 0.144.

Computing by hand the calculations presented above is highly laborious and time consuming work, especially when a large number of nodes are involved. And so, Mathematica (Wolfram, 1999) routines were developed to automate the calculations of path compactness and path status metrics. Mathematica was chosen since it is a powerful tool that combines symbolic manipulation, numerical mathematics, outstanding graphics and a sophisticated programming language to perform mathematics calculations with versatility (Abell & Braselton, 1994). A sample of the Mathematica codes that were used in this study is attached here:

The StratumCalc2 routine provides more efficient stratum calculation based on an adjacency matrix limited to the number of distinct nodes represented in the path record. Total number of nodes in the path web is similarly based on the distinct node entries in the record (i.e. nodes = nodes visited, not nodes in the handbook.)

```
StratumCalc2[InFile_] := Module[{k, c, n, r1, c1, c2}, DataFile = InFile;
For[k = 1, k ≤ Length[DataFile], k++,
adjmatrix = Table[0, {r, 1, Length[Union[DataFile[[k]]]}, {c, 1, Length[Union[DataFile[[k]]]}];
DataFile[[k]] = ConvertList[DataFile[[k]]];
For[c = 1, c < Length[DataFile[[k]]], c++,
{If[DataFile[[k, c]] == DataFile[[k, c + 1]], Continue[]},
adjmatrix[[DataFile[[k, c]], DataFile[[k, c + 1]]] = 1]]; distmatrix = adjmatrix;
For[n = 1, n ≤ Length[distmatrix], n++,
For[r1 = 1, r1 ≤ Length[distmatrix], r1++,
For[c1 = 1, c1 ≤ Length[distmatrix], c1++,
If[distmatrix[[r1, c1]] == n, For[c2 = 1, c2 ≤ Length[distmatrix], c2++,
If[distmatrix[[c1, c2]] == 1 && distmatrix[[r1, c2]] == 0 && r1 != c2, distmatrix[[r1, c2]] = n + 1,
Continue[]]], Continue[]]]]; transmatrix = Transpose[distmatrix]; absprestige = 0;
For[q = 1, q ≤ Length[distmatrix], q++,
absprestige += Abs[Plus @@ distmatrix[[q]] - Plus @@ transmatrix[[q]]];
If[EvenQ[Length[distmatrix]], stratum = N[ $\frac{\text{absprestige}}{\frac{\text{Length}[\text{distmatrix}]^3}{4}}$ ],
stratum = N[ $\frac{\text{absprestige}}{\frac{1}{4}(\text{Length}[\text{distmatrix}]^3 - \text{Length}[\text{distmatrix}])}$ ]]; Print[stratum];]]
```

Analysis of qualitative data

Qualitative data repeatedly collected and measured at multiple points over the period of the six phases of this study was content analysed. Content analysis of a body of data gathered from a series of data points defines a thoughtful and systematic set of procedures for the rigorous analysis, examination and verification of the descriptive content (Flick, 1998; Mayring, 2004). Content analysis is a research tool focused on the actual content to determine the presence of certain words, concepts, themes, phrases, characters, or sentences within texts or sets of texts and to ascertain this presence in an objective manner. Krippendorp (2004) asserted that content analysis is an unobtrusive research technique for making valid, meaningful inferences from large amounts of textual data on the contexts of their use. Content analysis takes texts and analyses, reduces and interrogates them into

a summary form so that a story can be drawn through the use of emergent themes to test or generate theories. Meanings of content analysis of textual data tend to be personal, multi-layered and located in specific perspectives and contexts.

Content analysis of qualitative data from this study was performed with the purpose of systematically organizing and presenting information such that comparisons, contrasts and insights can be made on students' problem solving performances and information searching behaviours for the six problems. The explanation of the main themes that organize the qualitative data analysis findings of this study allow readers to vicariously experience these descriptions and construct their own understandings of applying these findings to other relevant contexts.

In this study the primary content analysis methodologies adopted was that of conceptual and relational coding methods. Conceptual coding analysis began with identifying the key research questions and choosing the sample population. Once chosen, the descriptive data was coded into manageable content coding categories. The process of coding is basically one of selective reduction, which is the central idea in content analysis. By breaking down the contents of materials into meaningful and pertinent units of information, certain characteristics of the relationship and interactions between information searching and problem solving was analyzed and interpreted. Relational coding analysis builds on conceptual coding analysis by examining the relationships amongst the different themes represented by the coding categories to detect similarities and differences in the approaches and

techniques of information searching used by students in attending to a variety of problem situations.

The process of content analysis began by first analytically parsing through and scanning the qualitative data sources such as reflection journal entries, survey feedback inputs to identify key issues, topics and ideas associated with the research focus of this study on the mediating effect of information searching on problem solving. Data material was then coded into different categories by grouping together recurring or similar themes. This process of coding was undertaken in an evolving and iterative manner over a significant period of time. Instead of applying a pre-defined, fixed set of codes in the analysis of the raw data, a more flexible and emergent approach was adopted in generating the codes. The researcher revisited and reread the data many times to ensure consistency, refinement, modification and exhaustiveness of coding in noting distinguishable patterns and major themes in relation to the research agenda of this study. These conceptual elements were then examined and interpreted for their rich meanings, insights and implications so that a cogent descriptive narrative could be told in enhancing our understanding of the dynamics of problem-based learning pedagogy. The main strength of this content analysis process was that it was done later without disturbing the research setting and the researcher was able to do the coding category generation after the event, not being motivated to prove or disprove hypotheses by gathering facts to support his propositions.

Trustworthiness of study

Triangulation is one important way to strengthen a research study design. Triangulation can be defined as a process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation (Stake, 1995).

Methodological triangulation (Denzin, 1978b) was primarily employed in this study: the use of multiple methods to study a single problem or program. In a mixed design methods study as was the case in this study, combining both qualitative and quantitative research methods enabled extensive and comprehensive research to be carried out. The quantitative methods empowered the research approach of this study to be objective, empirical and unbiased. On the other hand, the qualitative methods handled in this study supplied a reflexive and subjective orientation in providing rich instantiations of the broader research agenda being investigated in this study.

Since both the qualitative and quantitative methods mutually inform one another, any bias due to exclusive reliance on one method can be rectified by using the other methods, with additional areas to be explored being identified. Triangulation allowed the shortcomings of one method to be offset by the strengths of the other. This prevented the researcher from accepting too readily the validity of initial impressions. Verification and validation of data analysis findings by checking for their consistency through the use of different research methods and data sources helped to augment the reliability and trustworthiness of the conclusions of this study.

CHAPTER 4: PRE-INTERVENTION QUALITATIVE DATA ANALYSIS & DISCUSSION OF FINDINGS

Pre-intervention survey

To determine the levels of Internet information search literacy skills development amongst participant students, a pre-intervention survey consisting of six open-ended questions was administered to students (a copy of the survey is attached in Appendix A). The survey addressed areas of students' misconceptions and informed the design of the elements of the interventionist framework aimed at raising students' information searching competencies. The survey findings also facilitated the provision of appropriate learning scaffolds during the intervention training phases.

Question 1

The first question that was posed in the survey was "How did you learn to use the Internet?" This question was of direct concern to the research agenda of this study since student responses to this question provided evidence about the key presupposition that Singapore students are indeed largely left to their own independent devices in learning Internet information search skills. These skills are not intuitive and are not easily picked up through self directed learning or peer-tutoring.

Twenty-two out of the twenty-five students mentioned that all their attempts at learning to use the Internet was mainly through self-taught efforts, random trial and error or help from novice fellow students or friends. Only three students indicated that they learnt to use the Internet through intentional instruction provided by their primary/secondary schools. Most educational institutions have ample on-site Internet access points but providing access alone is simply not enough. The student feedback to this first question provided evidence that there is a lack of formal learning of information search literacy in schools and tertiary institutions. This issue is of significant importance and directly impacts polytechnic students since for many of them the polytechnic might be the last exit point of their formal education before they enter the adult working world. The working world is increasingly becoming digital information orientated, with prevalent dependence upon the Internet for information to enable problem solving and decision-making.

Question 2

In response to the second question in the questionnaire on planning searches before actually carrying them out, and if so, how they did it, twelve out of the twenty-five students replied that they do not really plan for a search and normally plunged headlong into searching for information. Some reasons ascribed by these students to such a tendency were lack of prior knowledge, skills and instructional training in understanding how information searches ought to be planned, the perceived waste of time and no recognition of any explicit need for modeling information planning and management. Many of the reasons raised by these students reveal their misconceptions or ignorance of

the utility of information search planning and organization in carrying out their search activities. Many of these misconceived notions were addressed during the intervention period in helping students to construct more effective Internet information search practices and become more accomplished problem solvers. The following are some sample reflections by students:

“Not really. This is because once I know of the topic that I am required to find information about, I straight away go to yagoohoogle to search for the topic. I never really like to plan for what to search before my research. I simply feel that it is a waste of time.” (student C)

“No, I do not plan because I think that the net is very resourceful. I just type in the words in the search engine and upon execution, the desired information would automatically appear.” (student J)

“No, I do not plan for the search. I do the search immediately without any planning.” (student W)

Only three students indicated in their responses that they would analyse the information requirements of a given problem solving task to examine for key words on the subject matter to be researched upon. One of these students (student H) commented thus, “Yes, I usually plan my information search. I first investigate what needs to be searched in the Internet by listing certain key words that might provide me with the information that I need or is close to what I need”. However, it was noted that none of these students explained the rationale behind generating keywords in carrying out information searching or specified how appropriate keywords could be effectively formulated.

Another eight students underscored the necessity of planning their Internet information search before actually embarking upon the search itself. Generally, these students knew that as with any other common everyday activity, planning is a crucial pre-requisite in Internet information searching endeavours to ensure attainment of successful problem solving outcomes. For example, one student (student Q) suggested that establishing a plan was critical for a fruitful search in order to narrow down the scope of search results and avoid being overwhelmed by an avalanche of irrelevant search hits. Student Q further reasoned that narrowing down the output of search results to more precise ones improves the search performance and facilitates finding needed information in the shortest possible time.

Though these eight students mentioned that they consciously plan their searches, they were however not able to explicate in a clear manner the ways in which they would frame their search plans. The arguments presented by these students either lacked coherence or were extraneous to the search objectives of the given task. The eight students could not translate their understanding of the need to plan into a viable blueprint of executable action to organize their information searching. This could largely be attributed to a want of proper knowledge in knowing how an efficacious search plan can be developed and implemented to locate desired information. For instance, one student (student N) responded that her conception of planning for an information search was simply reproducing the given search question as the query term in the search engine and seeking targeted information. Though student N was aware of the importance of planning for information searches,

her reflection indicated her misinformed understanding of what actually constitutes effective information planning. Attached are a few typical responses of this category of students:

“Yes, planning is important to finding the information we want. Not too sure how it is done or of any particular techniques. But I know that otherwise time will be wasted.” (student B)

“Yes, I plan a search by relating the issues I am exploring. I guess in this way the information I am searching for would be relevant to the topic.” (student T)

“Yes, I plan my search by looking in the Net for answers and then recording everything I find.” (student V)

Only 2 discerning students (O and F) emphasized that planning for an Internet information search involved mentally mapping out a repertoire of search strategies and evaluating these strategies for their efficacy before actually executing the search. These students realized that constructing such cognitive roadmaps allowed them to better frame terminal search goals and have a better grasp of the sequence of actions they needed to undertake in achieving these goals. Planning beforehand allowed them to check their own progress during the search process and adopt more responsive strategies of information seeking. In short, planning for a search ensured that the search becomes more systematic in its structure and helped to avoid the frustrations associated with haphazard, random searching. The two students also proposed a plan that allows them to organize and manage the search process more productively. The students suggested that the process begins with

formulating in the mind a list of what is to be searched for and then identifying information needs by carefully selecting broad themes for exploration. The next stage would be assessing the appropriateness of various search strategies and sieving out the better ones before trying them out in action. Student O confidently remarked that “I usually begin my search by mentally planning for it in my brains, trying different options and if my search ends in success, I would gladly share the technique with my team mates.”

Question 3

The third question queried on students’ knowledge of search tools and the reasons behind their choice of search tools in carrying out their information searching. Almost all the surveyed students specified search engines as the common search tools they frequently access. Effective users of Internet information must first be effective searchers in trying to locate information found in the Web. Todd (1999) pointed out that effective searching of the Web requires knowledge about how search tools such as search engines function, which particular search engines matches specific types of information demands, what kinds of information access search engines specialize in and how the search engines index information. Generally, students’ responses to this question were brief, shallow and superficial, without delving into the specific details of which search engines best handle queries on particular information subjects and topics. Some of the explanations proffered by students contained misconceptions or were driven by popular choices and conveniences of access. None of the students could explain the ways in which search tools such as search engines work, the differences between various

search engines, their individual strengths and drawbacks and their focal areas of search expertise. Attached beneath are some sample inputs supporting these findings:

“I use search engines that most people commonly use.” (student J)

“I prefer search engines that give me the most number of hits for the information need I have.” (student A)

“The ones that give the most specific searches to the things I am looking for.....search engines that are generally reliable.” (student V)

“By listening to my friends and through experience.” (student E)

“The search engines that are easy to use and have most information.” (student G)

Question 4

The fourth question in the survey probed students' patterns of preferences in using search engines and their supporting reasons. Not surprisingly, a majority of the students i.e. twelve students mentioned Yahoo! and another eight students stated Google. Yahoo! and Google were the two most popular choices of search engines amongst Internet users of all ages. Three students also specified MSN, Ask Jeeves, Lycos and Ask.com.

Some of the reasons attributed by students to their preference for Yahoo! and Google include the wide popularity of these search engines, unfamiliarity with other search engines, the perceived relevance of the search results listed and the convenience of the features provided including offering of tool bars and presentation of brief information statements on each search result. Only one student X made the compelling statement that “there is no

one search engine I stick to....usually, I run multiple searches simultaneously and get a variety of results to choose from.” Another student Z stated his preference for Wikipedia in looking for information pertaining to basic sciences. One well-informed student F referred to Dogpile since it integrates the searching powers of Yahoo!, Google and Ask Jeeves. She argued that Dogpile’s capability to present an integrated compilation of the search results of multi search engines positioned it as a better and more relevant information search tool.

Question 5

The fifth question was an extension to the fourth: “Do you use multiple search engines in doing your information searching? Why so?” The objective of this question was to investigate students’ familiarity with the plethora of available search engines and their awareness of which of these search engines best suited their contextual needs. Vansickle (2000) argued that using multiple search engines allows for more extensive searching of the Web since even top ranked search engines have a relatively low degree of coverage overlap with one another. Todd (1999) stated that students needed to be informed that simple searches using a single search engine will not always return the best results since even the best search engines are slow in indexing information. Howe and Tillman (1999c) cautioned that searchers should learn how to use approximately two or three search engines well rather than learning just the bare necessities of several.

Significantly, twelve students responded that they use only one search engine to carry out their information searches. These students did not realize that one single search engine would not fully satisfy in entirety all their information needs. Search engines can be differentiated by the search algorithms they employ to perform their searches and each search engine has its own strengths and weaknesses. Furthermore, certain search engines specialize in focusing their search interests on specific areas of expertise. The choice of use of a particular search engine is determined by the parameters of the information requirements. Generally, accessing multiple search engines would be a more advisable technique since the information output would be more comprehensive, with a greater degree of success in finding relevant, cross-referenced information. Of greater concern were some of the misconceptions that surfaced in attempts by students at justifying the use of one search engine to execute their searches. For example, one student M argued that “I believe that not many people can multi-task and handle the complexities of various search engines. Personally, I usually use Yahoo! since I think it is the best and serves all my needs.”

The remaining thirteen students gave the feedback that they usually use multiple search engines in performing their Internet information searching. Though, there evidently was a lack of depth in the explanations provided by the students on the underpinning reasons for their use of multiple search engines, at least, at a fundamental level, they were able to recognize the benefits of leveraging upon multiple search engines. Though these students cannot be considered as expert Internet searchers, the ubiquitous availability

of computers and Internet access, both at home and in school, has undoubtedly acquainted students with a basic overview of the structure of the Internet and the common search tools it offers. Only two amongst these thirteen students highlighted the opportunities for cross-referencing the search results produced by different search engines for the same query. As one student H poignantly expressed: “By trying my search in multiple search engines, I am better able to compare and contrast the information presented in the different results of the search engines. I can then filter out and use the reliable ones.”

Attached are some excerpts from the responses of these thirteen students to question 5:

“Yes, using various search engines is useful. Usually, they produce different search results and so I will have access to more information to do my research.” (student I)

“Yes, I use both Google and Yahoo search engines. This gives me a wider and broader range of search results. I have formed this understanding based upon my previous Internet activities.” (student E)

“I like to use multiple search engines since it allows me to find as much information as I possibly could, making my research more constructive.” (student T)

“Different search engines search in different ways and conventionally, present the result hits in the order of frequency of access by other Internet users. Each individual search engine has its own merits and

strengths. Using multiple search engines can ensure that all information required of is there and nothing has been left out.” (student R)

Question 6

The sixth question that was posed to students in the survey was “Do you think there are any similarities/differences in the ways different search engines work? What would they be?” This question was framed in alignment with the objective of investigating students’ awareness of search engines and the structural similarities/differences of the search methodologies employed by these search engines. This question was also intended to elicit students’ perspectives, if any, on the strengths and shortcomings of popular search engines in their responsiveness to dealing with information requests. Nine students provided the honest feedback that they did not know or were not sure if there existed any differences/similarities in the ways in which the variety of search engines operate, with one student commenting that he never really felt it was a critical issue to want to find out more. Six students were of the erroneous opinion that there are no differences between the different search engines in terms of their functional attributes. They had the misconception that all search engines search for information in the same manner and the information displayed upon initiating a search request would also be similar. Students’ feedback reinforced the dominant finding that participant students obviously lack robust Internet information search literacy acumen.

The remaining few students understood correctly that there were some underlying similarities as well as differences between the search engines. The similarities include the aim of searching for relevant information and ranking the search results according to a defined algorithm. Some differences between search engines that were highlighted include the distinct ways in which information is processed and presented, the differential search scope and output as well as varying emphasis on particular keywords. From a conceptual level of analysis, a number of entrenched misconceptions were again exposed in students' explications. For example, one student K commented that some search engines require a few keywords to execute a search whereas other search engines need part of a sentence or a complete sentence to perform a search. Student K failed to provide necessary supporting evidence to back-up his unsubstantiated claim. Another student D had the misconceived notion that search engines produced varying output due to the differences in speed at which the search engines work to retrieve information!

Only three students contemplated deeper by providing anecdotal explanations of the working differences they had experienced to exist between the different search engines. Unfortunately, all three of them limited their ruminations to Yahoo! and Google only. Though none of them explained the reasons, this preference for Yahoo! and Google, as explained earlier, could be attributed to the soaring popularity enjoyed by these two search engines amongst Internet users. Some of the claims made by these students, based upon their prior interactions with the two search engines, could not be ascertained for their veracity. Nevertheless, unlike their peers, these three

students had invested more thoughtful thinking in responding to this survey question - something indeed noteworthy. The following are the cogitations of these students:

“Yahoo! uses tabs that narrow down the range for easier research whereas Google has a smaller range of tabs making it less user friendly.” (student X)

“Both Yahoo! and Google are almost the same but I feel that Google provides better details for more ‘serious’ matter e.g politics, medical stuff etc whereas Yahoo! provides better info for entertainment/leisure issues.” (student O)

“Both Yahoo! and Google give general results that cover a wide field. However, Yahoo! is more orientated towards industrial sites, thus producing more accurate results related to industrial matters.” (student H)

Pre-intervention reflection journal

Prior to the intervention training being administered, participant students were instructed to ponder over the following reflection trigger and articulate their thoughts in their electronic reflection journals:

- (1) What are your views on using the Internet as a learning tool to search for information?
- (2) What strategies or techniques do you use in conducting an information search in the Internet?

The first part of the trigger was aimed at eliciting students’ perspectives on how they perceived the usage of the Internet as an information medium in

accomplishing problem solving. Students' anecdotal perceptions, preferences and dispositions towards Internet information searching were also analysed from these responses. In the tertiary institution in which the participant students are enrolled, the Internet plays a vital role in shaping research and problem-based learning activities. Thus, students have rich, first-hand experiences interacting with the Internet on a daily basis and are able to comprehensively present authentic feedback on the use of the Internet as an electronic information platform supporting problem solving.

The second part of the trigger hoped to draw informed understandings of the catalogue of strategies and techniques, if any, employed by students in their attempts at navigating through Internet information in search of needed answers. This could provide meaningful insights into students' current knowledge, perspectives and competencies on how they model their information searching approaches.

Students' responses showed that generally they were aware of the potential of the Internet in furthering learning. Due to the long durations of exposure to the Internet, both at home and in school, for educational as well as entertainment purposes, students have a reasonably good overview of the structure of the Internet and the ways it functions. Most students were generally able to distinguish between the benefits and pitfalls of working with the Internet.

The Internet as a learning enabler

An overwhelming majority of twenty-two participating students underlined the positive impact of positioning the Internet as a vital information provider and problem solving enabler in tertiary institutions. Only three students expressed skepticism on the constructive role the Internet could play in promoting meaningful learning. Even then, some of the concerns raised by these students were neither substantive nor convincing. For example, student C highlighted the difficulties encountered in navigating through and locating desired resources within the expansive information landscape of the Internet. He likened the endeavour to searching for a needle in a haystack. He pointed out that surfing on the Internet, exposed the computer/laptop system to the menace of viruses, risking disruption to the healthy functioning of the system. Student J felt that at times the Internet search harvests information output that is too generic, unfocused and diffused. Though there is some credibility to these claims, students did not realize that developing sound information searching and PC maintenance skills is the key to resolving many of the stated problems without resorting to rejection of the Internet and its information potential.

The Internet as an information repository

Twenty-one students repeatedly used words such as 'convenient', 'helpful' 'useful' in describing how the Internet helps them in their information searching. They found the Internet to be a powerful, invaluable and versatile information repository that facilitated quick and easy access to a wealth of educational resources at the click of a fingertip. Student S commented that the

information found in the Internet is presented in multimodal formats, involving a combination of text, pictures, audios and animations, whereas traditional textbooks features information in predominantly textual representational modes. This she reasoned explains the positive correlation between Internet-oriented problem solving experiences and improvement in learner motivation. Student Z remarked pertinently that training students to be effective Internet users prepares them to operate comfortably well within the increasingly prevalent technology-centric culture of workplaces. Student H suggested that the Internet unlike traditional pedagogies “allowed for independent learning and inspired creativity.” Moreover, updated information on global happenings such as recent breakthroughs in scientific research, developments in the international business scene could instantly and easily be accessed in the Internet.

The shortcomings of the Internet

Though emphatic in stressing the strengths of harnessing the power of Internet, surprisingly, fifteen students also discussed at length the immanent drawbacks of the Internet. It is indeed commendable that without being carried away by the Internet hype and erroneously believing in the absolute good or infallibility of the Internet, these students had reflected on the potential instructional conundrums posed by the Internet. Some of these students were able to articulate well the caveats associated with Internet usage. Nine students mentioned that the copious amounts of information presented by the Internet in response to a query often could be overwhelming and distracting, with many of the listed hits being irrelevant to the search focus. This results in

laboriously scanning the hits for their appropriateness and sifting out the relevant ones from those irrelevant. Students complained that this often required excessive amounts of time being spent, with the problem becoming exacerbated when the search query had been poorly constructed. Twelve students underscored the difficulties faced in assessing the credibility and fidelity of information hosted by the Internet since anyone can easily erect a website and post information in cyberspace. Thus, the quality and reliability of many online resources are invariably questionable. Students, especially those with a lack of competent information literacy skills are susceptible to accepting inaccurate, biased information masquerading as being legitimate to be valid. This could result in misinformation being appropriated by students.

General lack of awareness of information search strategies

Though participating students had a working knowledge of the functional mechanisms and tools of the Internet, what was strikingly lacking in students' reflections was cognizance of the various information searching strategies that underpin successful information seeking. Students had rudimentary understandings of the multiple search approaches that could be adopted to mine the Internet for relevant information. In fact, upon reading the reflection question, students having never heard of the term 'Internet information search strategy/technique', were generally confounded by the term. They were unable to define their search objectives and how these goals could be accomplished. As student W aptly put it, "I never really use any strategies or techniques when searching. This is so since I am not good when it comes to Internet searching." This response is telling in light of the fact that

though these students were comfortable searching the Internet, due to a dearth of knowledge on competent search tactics, in reality, students were unable to strategically optimize their search attempts at information gain. Twelve students could recall only one search strategy - the popular and commonly used search engine and keyword search technique. This compelling evidence is indicative of students' limited knowledge of Internet search devices and their simplified notions of how they work. Attached is a sample of typical responses from students:

“When I search for information, I usually go to search engines and type in the keywords I am looking for. Then I will select the one that has the information closest to what I want and I will read through the content.”

(student A)

“I will usually use search engines. I will pick out the keywords from the information I need to find and type them in the search engines. Usually by doing this, the range of results will be huge. Thus, I will need to read through the links and pick out the relevant information.” (student G)

“If I were to search the Internet for information, I would make use of the online search engines like Google, Yahoo, Altavista, Search.com, etc. I would then type in the key words of what I want to search for into the search bar so as to obtain a more relevant search result.” (student D)

If these responses are analysed further, what is revealing is that most of the respondents mentioned Yahoo! and Google as their preferred search engine choices to carry out their information searching. Though Yahoo! and Google are the most popular search engines, students have questionably

interpreted this preference to mean that these two search engines were necessarily the best or would provide the most exhaustive search results. Students appeared to be unaware of the plethora of other available search engines that could just as effectively be employed, since no one search engine can comprehensively present all information related to a query. Students apparently were unaware that search engines varied in their search capabilities and employed different search logic and algorithms in enacting their search operations. Some typical sample responses from students in this regards are as follows:

“I would always use www.google.com as the search engine as it has the ability to search for only Singapore sites which are usually the more relevant ones. Furthermore, Google contains ‘much more’ information than yahoo (another preferred search engine) based upon my searching experiences.” (student K)

“In terms of search strategies and techniques, in searching for information on the Net, I like to use Yahoo.com & Google.com. I find that these two search engines normally produce the most & best results in terms of websites.” (student V)

“When I use the internet, I only use yahoo to find information since it satisfies all my needs. I don’t really know how to use other search engines as well as I am not familiar with them.” (student Y)

Misconceptions of students

Some of the responses on this theme also highlighted varying degrees of students’ misconceptions. For example, student E had the flawed

understanding that only Google had features that allowed configuring a search to be limited to a localized focus on Singapore websites or websites hosted by Singapore-based web domains. Student C was of the opinion that since the now defunct Yagoohoogle search site juxtaposed the search results of both Yahoo and Google search engine, by default, it was the best. He seemed not to know that though Yagoohoogle presented a combined presentation of the individual set of search results from the search engines, this was a compressed version of the total search output of the two engines.

Use of search engines and directories

Only two well-informed students, F and X mentioned that besides search engines, periodically they also make use of search directories. They justified their choice of using search directories by correctly reasoning that search directories, having been developed by human indexing, tend to produce more reliable and relevant search output listings. Based upon prior anecdotal search experiences, student F noted the drawbacks of typing in long search query phrases that have been reproduced word for word from the research questions in the given task. The user is then faced with the laborious task of having to sieve through an avalanche of search results to locate the ones that accurately match the search focus. Student F intelligently suggested the strategy of maximizing the number of search queries and minimizing the number of words per query by breaking down the main research question into its component sub-parts. The information collected in response to each of these queries could then be integrated into a coherent composite whole and presented as the solution.

Use of information search techniques

Only student O articulated the application of known site strategy as one option she would pursue if she knew of specific websites from prior experiences that contain information on the subject matter she wants to explore. Astutely, she also suggested the technique of variations by entering multiple alternative keywords in searching for the same piece of thematic information. “I would also use specific websites for different subjects I am researching on. For example, for science, I will go to a certain website which has tutorials on science concepts such as <http://howstuffworks.com>. I will also use different keywords although I am looking for the same information.”

Only two students (L and X) mentioned the use of the helpful ‘+’ arithmetic Boolean operator when constructing keyword search phrases. Applying the ‘+’ operator ensures that the search output produced by the search engines is more precise and corresponding to the search quest. Of concern was also the finding that only student L pondered over the necessity of entering quotation marks to define search terms more precisely and instruct the search engine to locate web content that contains the specified words in the order mentioned within the quotation marks. These indicated students’ ignorance of the utility of Boolean operators in streamlining the search process and ensure its successful fruition.

Based upon the pattern of findings, it is obvious that the majority of students were deficient in their knowledge of a range of information search strategies. Students obviously needed explicit, structured instructional mediation to raise their capabilities to become skillful Internet information

searchers. One student candidly admitted thus: “I believe that there are still many other ways of searching for Internet information but I guess I am yet to gather the necessary skills.” (student Y)

Pre-intervention phase problem 1 (Well-structured)

The problem entitled ‘The Package’ was given to students during the pre-intervention phase.

The Package

There is an aeroplane that is flying approximately 2 to 3 kilometres above you. As you look up, you see a package falling out of the aircraft. How far do you have to walk from where you are to retrieve the package?

This problem is a constrained, well-defined problem. In Jonassen’s (2000) typology of problems, this problem would be classified as a story problem. Situated within a brief story, this arithmetic problem tests students’ mathematical and scientific conceptual understanding. Students have to make reasonable assumptions based upon the limited number of parameters embedded within this problem. The problem is well-structured since it requires the contextual application of a finite number of regular concepts, rules and axioms to be able to solve it in a mechanistic and sequential manner. Analytical and diagnostic reasoning has to be applied, with identified variables being manipulated using a set of logical operators, scientific principles and algorithmic procedures to seek solutions to this problem. Overall, these solutions tend to be convergent, highly probable and easily knowable.

In tackling this well-structured arithmetic problem, students within their teams collaboratively had to leverage upon their individual prior knowledge expertise in recapitulating related scientific concepts and theories. Active group-based discussions and brainstorming helped in this process. Previously not learnt or missing factual information had to be searched for to acquire new knowledge. In analyzing the information needs of this problem, students enumerated a number of important conceptual issues in their first meeting templates warranting further research or factual information exploration to solve the problem. Some of students' inputs included the distance to be walked to recover the package; the direction and speed of wind, if acting; weight and velocity of the package; related physics/mathematics principles and equations; actual vertical height of aeroplane; speed of aeroplane; energy gained or lost during the fall of the package; air resistance; weather conditions; total time taken for the drop; angles of elevation; the value for acceleration due to gravity.

Results

Teams 1, 3 and 4 made the right assumptions and successfully solved this given well-structured problem. This they did by first calculating the unknown parameter of time taken for the package to land on the ground by using the kinematics formulae $s = ut + 1/2at^2$. Substituting the rounded up figure of 10 m/s^2 for acceleration due to gravity and rearranging the variables in the formulae, the time taken for the package to drop was easily found. Applying this known time factor students in these three groups used the formulae $distance = speed \times time$ to derive the desired answer for the distance

to be walked to recover the package. Team 2 only managed to partially solve the problem while Team 5 was unsuccessful in solving the problems since either they made the wrong assumptions or conceptually applied incorrect formulas.

Discussion

The results support the argument that well-structured problems are more easily solved through prescriptive ways by using an organized set of logical operators and procedures. Students recognized the problem statement to be a physics and/or mathematics related algorithmic problem when the problem statement was first issued to them.

The problem solving events for this story problem began with students having to conceptualize the problem space of the problem and recognise the variables that define this space. Then, students had to assign values to these variables that are acceptable or defensible within real world contexts. If students lacked prior knowledge in determining the variables or comprehending the conceptual meanings conveyed by these variables, they needed to search for information in the Internet to fill in the gaps in their understandings. For example, some students who did not readily know realistic estimates for the traveling speed of a plane had to consult physics and/or mathematics Internet resources to gather more information.

Tenable assumptions also had to be made in order to make headway with problem solving. The teams that successfully solved the problem made correct initial assumptions in relation to the context of the problem scenario whereas the unsuccessful teams failed to do so. For example, the problem

statement mentioned that the plane was flying at a height of 2-3 km and students had to assign a fixed value to the vertical height, say at a constant 3 km height above ground level. In justifying that the assigned values are indeed reasonable, students had to convincingly explain the underpinning rationale behind their specific choices and decisions. For example, if students placed the flying speed of the plane to be 500 km/hr, they had to substantiate this assumption with the valid explanation that cargo planes normally tend to travel at these speeds at relatively low heights of about 3 km. By consensually making reasonable assumptions, many of the nonessential variables were eliminated and focus narrowed down on those that had a direct influence on where the package will land. For example, the three teams that successfully solved this problem deduced that the horizontal speed of the package was the same as the velocity of the plane. This proposition was justified since students invoked Newton's first law of motion in their argumentation and assumed the absence of air resistance. Newton's first law of motion stipulates that an object in motion is predisposed to stay in motion and an object at rest continues to do so unless an external, unbalanced force acts upon it. Discounting air resistance meant that there was the full impact of acceleration due to free fall, with gravity having the same effect on all objects. Thus, the mass of the object had no influence over its acceleration and the time it takes to hit the ground. If students had taken into account air resistance, this would have unnecessarily complicated the problem since the shape of the object can affect its speed when it falls. Hence, in this problem, it was reasonable to exclude air resistance to ensure better focus in getting an approximation of where the

package will land. Another legitimate supposition that was considered in simplifying calculations was that the package did not have an initial velocity since it was not thrown out with force from the plane. It was simply dropped. It was also not very unreasonable to exclude wind resistance since the conjecture was that the weather conditions were ideally suited for the food drop.

Thus, by making valid assumptions and eliminating non-essential variables, students were able to better visualize the logical structure of the problem and metacognitively try out heuristic strategies to seek effective resolutions to the problem. Once relevant variables had been identified and plausible values assigned to them, students had to explore the relationships between these variables in the form of established formulas. Connections were drawn between these variables since in the scientific domain variables do not exist independent of each other. A formula is an expression of the conceptual links between different variables. The contextual values applied to the variables dictate the actual output of computations and the formulae dictates the logical structure of the calculations. In determining applicable formulas, students had to analyze and apply the supporting physics principle that an object falling at an angle will hit the ground at the same time as an object falling vertically straight down. Either through recalling previous knowledge learnt during their science lessons or by accessing Internet resources and researching for new information, students were able to correctly grasp that the trajectory of the dropped package would be a parabolic projectile motion. This then allowed the unknown time factor to be computed

using the formulae $s = ut + \frac{1}{2}at^2$. The final step in concluding this well-structured problem solving process involved applying this value for the time factor into the formulae $distance = speed \times time$ to find out the required distance to be walked to pick up the dropped package.

Students' reflection journal inputs

The following reflection journal trigger, consisting of two component parts was posed at the end of the problem solving session for students to post their reflective comments on the learning gains for the day:

“How did you go about solving today’s problem? How did you go about searching for information needed to solve the problem?”

Life skills and analytical skills

Students generally were of the opinion that solving this problem equipped them with life skills that prepared them for the demands of the working environments they will be entering to upon graduation. As student D appropriately put it, “I have learnt a bit on how to deal with my working life in the future. I believe that this learning experience is good since in working life almost everything is not spoon fed.” Student Q mused that this problem encouraged her to engage in analytical thinking: “trains us to think out of the box and to have an inquisitive mind. We asked ourselves many questions in finding the solution in the quickest and most efficient way”. Twelve students remarked that this problem required a combination of mathematical, physics and logical thinking. Physics and mathematical knowledge was necessary to grasp fundamental principles whereas formulas and equations had to be

correctly applied. Logical thinking skills were needed making cogent assumptions and evaluating proposed solution plans.

Collaborative synergy

Significantly, ten students highlighted that collaboratively working within teams to solve the given problem created shared contexts for meaningful learning to occur. Indeed, collaborative learning is a vital dimension of problem solving since it empowers students to engage in dialogic discourses, generate higher-order thinking and actively build up teams' collective knowledge capital. This results in a pedagogical ethos where interactive inquiry is promoted and knowledge is viewed as the common property of a learning community.

Students emphasized that tackling this kinematics problem generated high levels of intellectual growth and synergistic energy. The co-operative problem solving experiences helped students to analyze the elements of the problem through the lens of critical openness and leverage upon the different cognitive strengths of individual team members to forge consensual solutions to the problem. Attached are some sample comments by students on how they gathered deeper insights into the problem and built up a broad base of content knowledge expertise by collaboratively tackling the problem:

“I already know something on projectile motion and Newton’s laws. So I willingly shared my knowledge with my team members and in the process of communicating with them learnt even more.” (student F)

“Luckily, we had a team mate who is good in Science and he led our discussions during brainstorming. Thus, his better understanding of relevant

concepts enabled us to also become familiar with these concepts and do more research on them.” (student G)

The Internet as the source of information

Be it for checking on conceptual reasoning before an assumption is accepted to be valid or for recapping previously learnt but forgotten formulas and equations or to acquire a deeper understanding of relevant scientific principles and rules, almost all the students indicated that they prevalently relied upon the Internet as their principal source of information. This is hardly surprising considering the fact that an efficient wireless networking infrastructure was in place in the polytechnic to allow students quick and convenient access to the Internet via their individual laptops. Corroborating this typical view, student A mused thus in her reflection journal: “My team mates and myself extensively used the Internet to search for needed information such as theories, formulas and other things we were unsure about.” Student P mentioned that “by searching for information in the Internet we came across physics resources on the concepts of ‘free fall’ and Newton’s laws of motion, reading which helped us to better understand various scientific explanations related to this problem.”

Learning problems encountered

Many of the learning difficulties experienced by students during this particular problem solving session could in effect be attributed to their self-taught, inchoate information searching skills. Students noted that the major obstacle they faced was in trying to locate the right resources in the Internet. Students were befuddled over the most efficient means of organizing their

information searching to acquire and use needed information. Students were unaware of the importance of developing coherent search objectives and plans. Most students preferred to constrain their searches to using a single search engine such as Yahoo! without realizing the functional strengths of the multitude of other search engines. They were not cognizant of the availability of other search tools such as search directories. Many students also had entered lengthy search phrases and at times, even sentences as search terms contributing to diffused search output. Overwhelmed with the large number of relevant hits, students tended to feel frustrated and were not able retrieve the information they need to be able to use it to solve the problem. This was generally indicative of students' poorly developed search skills and lack of awareness of different search tools and techniques to be able to formulate more precise search terms and maximize their search efforts.

The difficulties faced during this problem-solving episode were mitigated by the fact that the problem is a well-structured one. Upon making reasonable assumptions, the problem becomes well defined and the information search scope delimited as well as bounded. Despite struggling with their lack of proficiency in effective information searching, through repeated attempts, students managed to locate relevant informational websites and successfully solve the problem. From the perspective of effective information searching methods, the attainment of this positive problem solving outcome seemed more incidental rather than purposeful. Thus, it was evident that students needed explicit instructional scaffolding to improve their Internet

information searching proficiencies and become more productive problem solvers.

Pre-intervention phase problem 2 (Ill-structured)

The next problem entitled 'Lets design.....' given during the pre-intervention phase is a typical example of a design problem found in Jonassen's classification of problem types.

Let's design.....

Space is very limited in Singapore and every square meter is precious.

In order to maximize space, design a 100 storey skyscraper that does not use lifts, staircases, or escalators.

This problem is a complex and ill-structured problem that requires students to think creatively. This design problem can be characterized as ill-structured since there are no easy or obvious textbook solutions that could be devised and the problem inherently has ambiguous specifications in relation to goals, configurations and outcomes. In addition, the problem has been framed with no clear demarcations of the boundaries of the problem space, thus mandating a flexible and innovative approach to resolving the problem. It possesses no pre-defined or fixed solution routes and calls upon the integration of multiple domains of knowledge expertise. Thus, a wide variety of skills need to be harnessed in order to metacognitively monitor and organize the problem solving process.

A design problem such as the one that was given cannot be solved through rigid, procedural methods of analysis and require students to engage

in higher-order problem structuring and reasoning. Tops-down means of task decomposition in problem solving will not be sufficient in analyzing the elements of this problem and generating feasible solutions. Embedded with many degrees of freedom in choosing solution paths, the output to this problem cannot be assessed easily in terms of right or wrong answers. In approaching the problem, the solver needs to construct design schemas based upon a combination of both pragmatism as well as inventiveness. The essentiality of producing artifacts as evidences to demonstrate competent levels of problem solving and lack of explicit criteria standards that inform evaluation of solutions contribute further to the complexity of such an ill-structured design problem. Students need to cultivate greater sense of commitment and perseverance in considering multiple perspectives of investigation in attempts at formulating defensible design solutions. Well structured problems by nature enable the neat transfer of propositional knowledge schemas and domain-specific systems of analysis to map out acceptable solutions. On the other hand, ill-structured problems such as the given design problem contain requirements that are both open-ended and ambiguous. As such, this problem calls upon students to tap both their prior personal knowledge in working with transport network systems as well as search for a wide pool of multidisciplinary information in producing viable design solutions.

One of the goals of this problem-solving episode was to promote the use of the powerful pedagogical technique of brainstorming to generate variegated solutions that satisfy the requirements of this design problem.

Orientating and familiarizing students with the mechanisms of brainstorming is vital to untangling the complexities of ill-structured problems. Team brainstorming plays a key role in fostering a congenial co-operative environment where individual team members are viewed as 'resources' of ideas in facilitating collaborative generation of a raft of plausible ideas. In the beginning, when generating different strands of ideas, students need to focus on quantity and refrain from unconstructive criticisms that hamper meaningful discourse from taking place. The key to effective brainstorming is to ensure that there is an uninterrupted exchange or flow of ideas. The greater the number of ideas proposed, the greater the chances of success in producing an effective solution. All ideas are potentially good and judgment of these ideas should be reserved towards the end of the brainstorming session. Unusual or unconventional ideas are welcome since they stimulate and add richness to the depth of on-going discussions. They may open new ways of thinking and provide better solutions than regular ideas. These ideas could be generated by considering alternative perspectives and standpoints. The last series of actions in brainstorming involve evaluation of these ideas for their viability and selection of the most appropriate ones to produce a workable design solution. Overall, this approach ensures that in consensually working towards producing convincing design specifications, the abilities to dialectically think in new ways, resolve conflicting perspectives and connect seemingly unrelated ideas to form coherent, new concepts is fostered in students.

In analysing the information needs of this problem, students noted in their first meeting templates that they had to find out more on the appraisal

criteria that had be applied in evaluating the quality and safety of submitted design proposals. They wondered whether internationally there are any other existing buildings that conform to the articulated design specifications and could thus be used as the archetype in prototyping their own designs. This task proved both exciting as well as challenging to students. Students also pondered on the attributes of robust ideas and how they could actively be generated through synergistic interactions.

Results

Team one suggested travelators as their preferred choice of transportation means in servicing the 100 storeys of the skyscraper. The following illustration titled 'The One Stop Sky' encapsulates their design ideas:



Figure 8: Team 1's design solution

Team two came up with the design prototype of a pulley system. The following diagram is a visual representation of students' design framework:

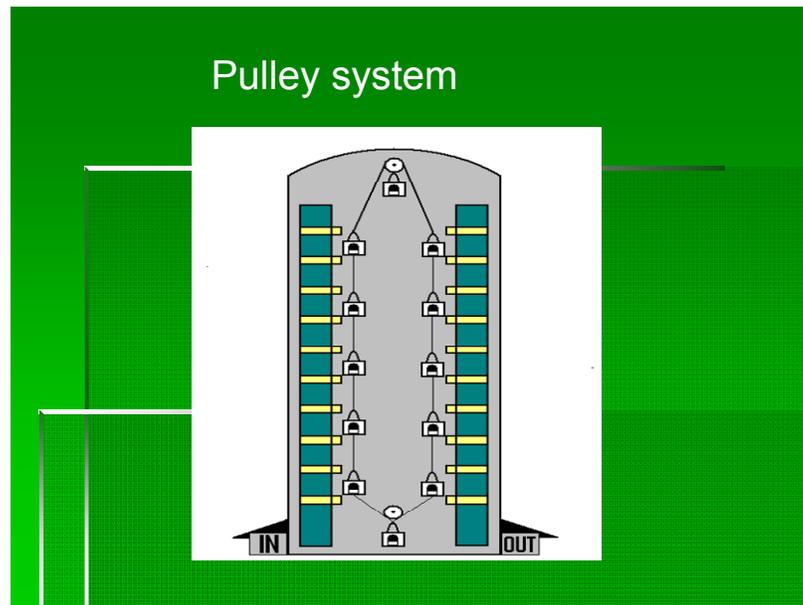
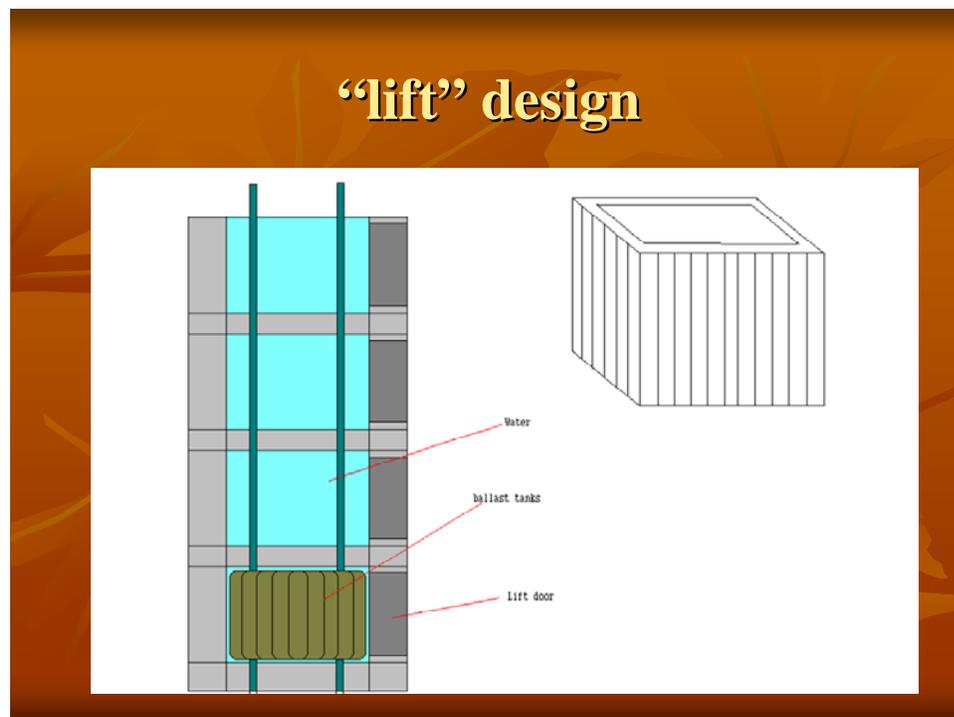
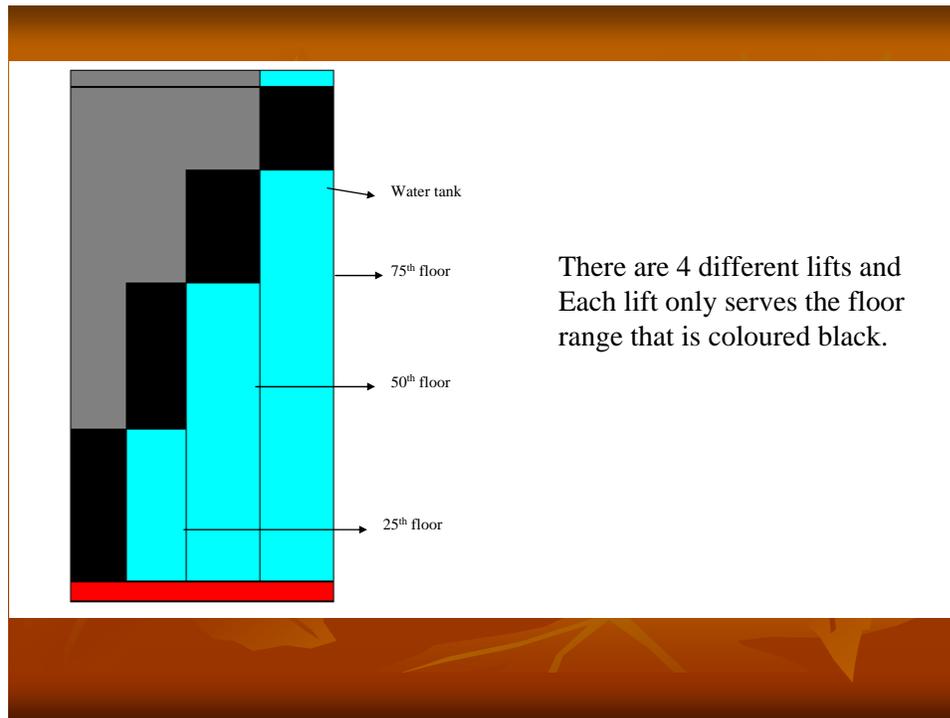


Figure 9: Team 2's design solution

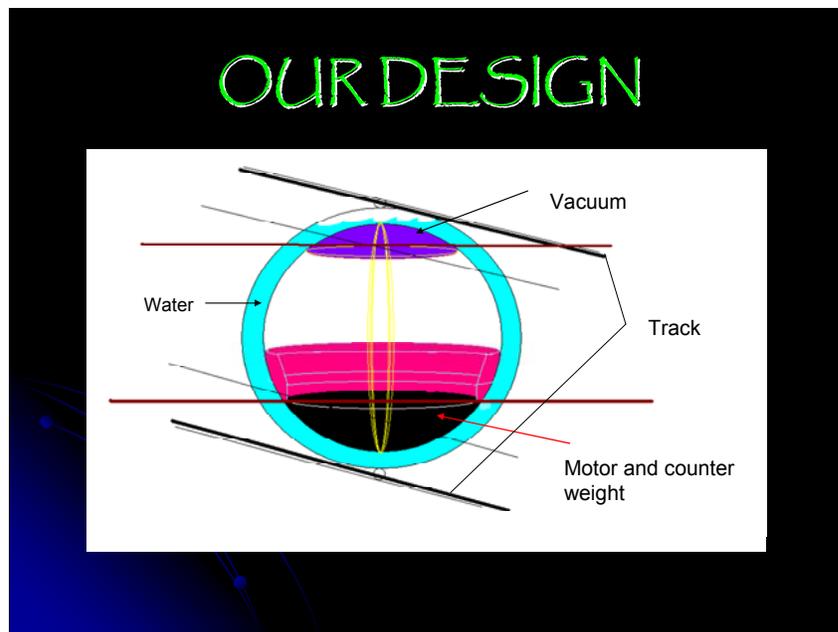
Team three chose a building design that focused on a ballast 'lift' concept.



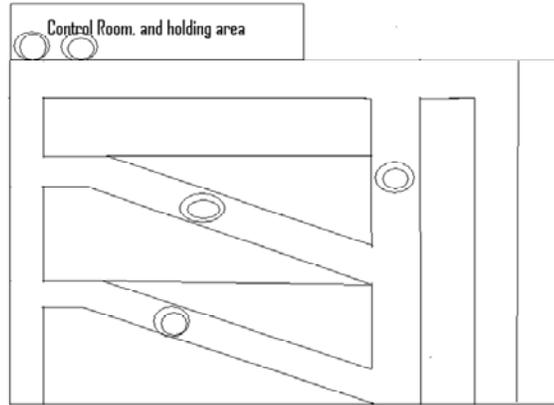


Figures 10 & 11: Team 3's design solution

Team four chose a spiral link concept as their design solution. The following diagrams represent the design principles of this sphere link model:



OUR DESIGN IN ACTION!



Figures 12 & 13: Team 4's design solution

Team five in their presentation proposed a design blueprint that was a combination of the architectural ideas and structural features of the Taipei 101 and Burj towers. The following diagram portrays the key components of the design model proposed by these students:

Our design

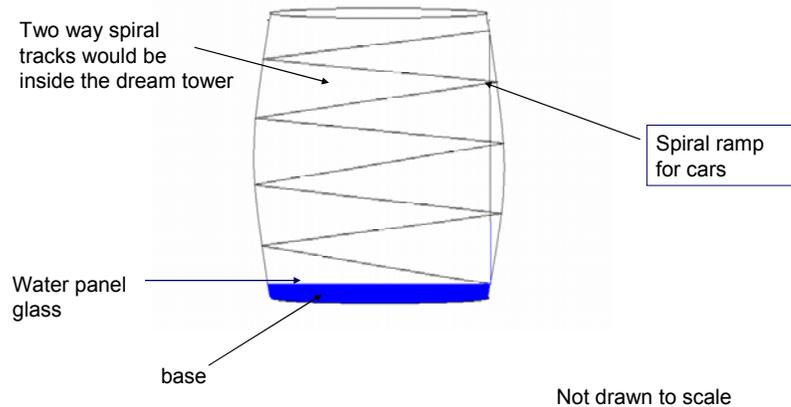


Figure 14: Team 5's design solution

Discussion

This being an ill-structured, open-ended design problem, most students were baffled on proceeding with brainstorming for ideas and faced numerous difficulties during the problem solving process. This is hardly surprising considering the constraints imposed by the problem - students were faced with a paradoxical problem scenario where the proposed design model had to be futuristic as well as grounded to an acceptable degree of realism. Students from team one initially were clueless on how to think out of the box and design an ingenious but defensible transport solution that is not associated with lifts, escalator and staircases. Team two's students highlighted that though they were easily able to generate a repertoire of possible ideas, most of them did not fulfill the conditions specified in the problem statement and they had difficulties selecting the one choice that seemed most plausible and acceptable. Being handicapped by a lack of architectural and engineering

foundational knowledge, students found it challenging supporting their designs with logical, compelling and scientific arguments. They were unsure of the assessment criteria to be referenced in evaluating the efficacy of their ideas. Students from group five pointed out that researching on a broad base of content information as mandated by the multi-dimensional focus of this unusual design problem was laborious, time consuming and often frustrating since requisite information straddles across multiple disciplinary domains of expertise. This required elaborate co-ordination and execution of effective search strategies to monitor and regulate search performance - skills which students evidently lacked and required further instructional training on.

In view of the stipulated constraints embedded within the problem trigger, normative solutions would not be adequate in satisfying the requirements of the problem. Thus, students were forced to think divergently and creatively. Not surprisingly, in the end, only two of the five groups were able to produce design models that were acceptable, resourceful and implementable. Teams one, two and five were unsuccessful in their attempts at solving the problem. Team three performed credibly well and team four produced the most impressive and sophisticated design solution for this problem solving task. This shows that students find ill structured problems much more difficult to solve than well structured ones such as the earlier problem 1 of this study.

Team 1 presented travelators as their solution plan. This group of students claimed that the originating sources of inspiration for their design conceptualization came from studying the transportation systems in place in

the tourist spot of Underwater World at Sentosa in Singapore and the Great World of China. They then synthesized these design elements in their design product. Travelators are moving walkways that could commonly be found in airports and shopping malls. Spirally built in slopes and winding their way around the exteriors of the skyscraper, travelators enhance productivity and save on energy consumption. The encircling travelators are reinforced with handrails for increased safety. Users could step off the travelators once they reach their intended destination levels. Students framed in their design two directions of travel for the travelators – one carrying users upwards from the ground floor to the hundredth level and the other, vice versa. Students deemed that it would take about 10 to 12 minutes to complete the entire journey through the 100 floors of the skyscraper – an unreliable and flawed estimate of analysis, considering the typical speed of a travelator. In addition, for streamlined access to the top floors of the building, students proposed that the 100th floor be reachable through a connecting cable car from another adjoining tower. This was yet another aspect of the submitted design solution that did not come across convincingly feasible, taking into account the huge costs that would be incurred in supporting its construction. Overall, the major drawback of this travelator design that worked against it during evaluation was the uncanny resemblance it had to escalators. The explained details of the underlying working principles of travelators closely mirrored those of escalators – thus lacking originality and violating the design criteria stated in the problem statement.

Team two had initially generated a number of preliminary ideas such as sports climbing, ferris wheel and abseiling. Weighing the pros and cons of each option and after much discussion, the team finally settled on the design prototype of a pulley system. Students in team two viewed that their solution plan of a pulley system would be able to carry a large number of passengers at a relatively moderate speed without compromising on safety. These students were of the opinion that such a pulley system powered by an electric generator is both a realistic and reliable medium of transportation in the absence of stairs, elevators and escalators. The sole carriage in the pulley system rotates only in a clockwise direction since students were of the opinion that such unidirectional movements would ensure savings in construction costs and traveling times as well as facilitate a less cluttered design product. The pulley system is configured to allow the carriage to stop at every level with mounted protruding platforms allowing passengers to conveniently access the carriage compartments.

One of the major shortcomings of this design proposal is that instead of being futuristic or novel, it is rather outdated and archaic – clearly lacking the expected flow of stimulating creativity and innovation. Students had erroneously overlooked the vital fact that especially during peak periods when called upon to service all the levels, the pulley system would become significantly incompetent and unproductive as it slowly inches its way upwards and downwards, stopping at every level. Thus, contrary to students' initial positive assessment, this could undesirably result in immense frustration due to long waiting times.

The students in team five decided on their integrated design of a spiral train and car ramp since they believed that there was a good fit between the design elements of these two buildings and the goals of the problem task. They had assiduously explored a number of alternative ideas including teleportation, rock climbing and magnet pull before zeroing in on this blended design involving spiral train and car ramp. The arguments students from this team placed in favour of their design plan were that it was rigorous and satisfied the four primary selection criteria items they referred to in assessing their choice i.e being logical, convenient, safe and multi-functional. According to these students, their design was a practical choice since it caters to the needs of a wide spread of people, including the elderly. It included useful features that enhance transportation convenience and afford ease of maintenance.

The two-way train track system allows for the efficient movement of commuters bi-directionally. One train travels upwards with the other coming downwards, stopping at every level. The train tracks are situated spirally within the interiors of the building, thus contributing to the convenience of commuters in easily boarding into or off the carriages at the desired floors. The train compartments are adequately spacious in size in order to accommodate a large number of commuters and ensure that inconveniences such as human traffic jams are avoided during peak hours. In addition, the skyscraper is strategically fitted with a car ramp system with tracks criss-crossing diagonally across the span of the entire height of the building. According to the students, this creates an alternative means of transportation for those who own cars and

wish not to be caught up in the hassles of using a public train system. The car ramps ostensibly also provide a conducive platform of parking for car owners inside the building itself.

One prominent reasoning flaw of this design model is the obvious fact that with the provision of car parking facilities and car ramp tracks running across the inside of the building, available space for the construction of floor tiers, shop lots and office cubicles is severely constrained! Though a unique design proposition, in terms of pragmatic considerations, it is not very defensible. Unless this skyscraper is showcased on the sole basis of an innovative transportation model, this design is not pragmatic. Compounding further the drawbacks, an elaborate arrangement involving both spiral train and car ramps exponentially escalates logistics and construction costs.

Team three decided on a ballast lift concept as their design solution. Though in essence, some elements of their design replicate the operational mechanisms supporting traditional electric-powered lifts, students had deftly injected a high dose of inventiveness and novelty by adaptively incorporating lifting principles employed by ballast tanks found in submarines. Some of the students in the group had prior knowledge and keen interest in the subject matter of submarines which they exploited well by conducting further information research and integrating the acquired information by skillfully modeling a ballast 'lift' design. These attempts at resourcefulness are indeed highly commendable and noteworthy.

Students in this group had during their initial discussions wrangled with a variety of options in exploring alternative ways of transporting people in the

building. The team was far sighted and astute in even generating ideas on how the architectural framework of the building itself could be uniquely fashioned in order to support innovative methods of transportation. For example, one of their original designs involved the conceptualization of a circular building structure in-built with a towering cylindrical core filled with helium. The cylindrical shaped 'lift' in principle harnesses the modus operandi of hot-air balloons with the four units in every floor accessing the single 'lift' through a common 'lift' lobby. Students decided to discard this design suggestion since one lift serving all the 400 units in the building is impractical and will result in extremely long waiting times. Moreover, helium filled 'lifts' pose real-time safety threats due to the highly flammable nature of helium gas.

After much consultative debates and analysis, students finally settled on the ballast 'lift' design as their end product artifact for submission. The design embodies a square shaped building that consists of a cylindrical core filled with water. There will be four separate lift shafts with the four 'lifts' serving a 25 floor range each. Slightly modifying the issued problem statement, students proposed the skyscraper to be 101 floors tall with 100 floors being accessible to the general public. From an engineering standpoint, this amendment in the height of the building is necessary to accommodate the functioning of the ballast tank 'lifts'. These ballast tank 'lifts' are the driving forces in the implementation of this 'lift' concept, with the 'lifts' ascending and descending when water is pumped up from above and below respectively. Thus, the 'lifts' are propelled up and down the shaft by the induced suctioning power. The vertical movements of the 'lifts' are guided in direction by four

sturdy rods spanning the entire height of the lift shafts. These rods also ensure that the 'lifts' are not susceptible to destabilizing turning effects. The lift shafts have been constructed in compartmentalized segments such that each compartment is structurally aligned to serve one level of the building. Each of these buffering compartments has been fitted with overhead and floor decks that have horizontal sliding opening doors. For example, if the passenger in the 'lift' wants to move a level up, upon pressing the button, both the doors of the floor deck and the overhead deck of the compartments corresponding to the levels above and beneath the current level occupied by the 'lift' slide wide open. This allows the water filling up the space of the compartment above to be drained down to the compartment below, thus creating a vacuum above that pulls the 'lift' up a level. A watertight walkway that attaches itself to the vertical 'lift' doors has been factored in the design in order to facilitate passengers' safe movements in and out of the 'lifts'. Though, this ballast 'lift' design may not stand up to rigorous scrutiny based upon established engineering principles and specifications, taking into account the level of physics knowledge participant students possess, this design is indeed an intelligent and inventive design solution.

Team four having considered a range of diverse ideas such as teleportation, mini-train, ferris wheel, jet pack and spiral express, finally decided on a well-thought out spiral link concept. Students from this group argued that they chose this design since it is inherently more complex and distinctively different. Students envisaged that their design plan is most likely implementable in the near future as it would be a close fit with advanced

technological capabilities probably available at that point of time. Besides scoring high in areas such as creativity and atypical uniqueness, the underlying chief strength of this spiral link design is that it is an integrated design combining the transportation powers of cable cars, roller coasters and slopes.

The sphere link system is fully automated and operationally controlled by a central command room functioning also as the holding area. The mobile spheres are guided in their movements along the tracks by a mechanical motor and the weight of the counter forming the base layer of the sphere. The network of tracks have been organized and laid out such that both movements in the vertical and sloping directions can be accommodated. Each sphere is reinforced with an outer covering ring filled with water to facilitate ease of movement and ensure comfortable rides. In addition, these dynamic spheres are fitted with quality seating facilities.

Significantly, this team of students chose to explain both the pros and cons of their design proposition – a positive and encouraging strategy implying that students were developing to be holistic thinkers. One of the strengths highlighted included the seating affordances for passengers inside the sphere links unlike the need to stand as it happens in normal elevators and escalators. This raises convenience and comfort levels a few notches higher. The average commuting speeds of these sphere links are also much higher than those of elevators and escalators, resulting in quicker traveling times. The spheres are fully capable of traversing vertically and along slopes. This means that passengers who wish to ascend or descend an extended span of floors to

quickly reach a destination level could access the ‘fast’ spheres programmed to run along the vertical tracks and stop only at pre-determined levels. Others could access the ‘slow’ spheres that slide smoothly along the sloping routes cutting diagonally across a smaller range of floors but halting at each of these individual levels to allow passengers to either enter or exit the spheres.

Students then proceeded to articulate the limitations of their design outline. Chief amongst them was the concern that the implementation of their design plan was contingent upon the pace of engineering and technological advancements in the foreseeable future. The sooner the supporting technologies are developed and made available, the greater the possibilities of quicker implementation of their design. Another pertinent drawback pointed out by students was the fact that electricity consumption for the continued operation of the sphere link system would be high since it is entirely electricity-driven. Yet again, how popular or of utility the system would be when the sphere link design materializes is questionable especially in the face of stiff competition from traditional, reliable transportation modes such as elevators.

Students’ reflection journal inputs

The following reflection journal trigger closely resembling the one associated with the first well structured, kinematics problem was posted and students’ contemplations collated for analysis:

How did your team brainstorm for ideas in tackling today’s problem?

How did your team go about searching for information to solve this problem?

Collaborative learning

Students' reflections generally revealed similarity in the strategies used to solve the design problem. These strategies, in essence, were inherently collaborative in orientation and empowered collaborative co-construction of ideas. Being an open-ended problem, students initially had to list down and accumulate as many ideas as they individually possibly could generate. Falling within a continuum, these ideas ranged from those that were realistic and implementable to those that were wild and futuristic. All ideas were accepted and noted, with none of them in the first instance being dismissed or criticized as being irrelevant or non-feasible. This created a convivial ambience where sharing and contribution of ideas was both welcomed and encouraged. Then, more consultative research was done on the Internet to mine for a larger pool of information that could effectively be tapped upon to validate the applicability or viability of the suggested ideas. This helped to streamline the process of evaluation of ideas, with the more convincing ones being retained and further modified or synthesized to formulate a persuasive design model that satisfies the requirements specified in the problem statement.

Some typical excerpts from students' postings are attached herein:

"Today's problem was a difficult task to us especially in the beginning. In real life we have never seen any building without lifts, staircases or elevators! But I think every problem has a solution. As a team, we worked cooperatively and did brainstorming. We talked a lot and everyone contributed ideas. Some ideas were impossible to be accomplished or crazy and stupid. Finally after some struggle we came up with a good solution." (student T)

“We thought of different ideas. At first we just threw in any ideas that came to our minds. This was necessary since our inspirations come and go. Each one of us gave one or two ideas at least. Then we carefully thought over whether they are reasonable, logical or relevant and eliminated those that were not reasonable enough.” (student B)

“Every member was asked to think of ideas to solve the problem. After that we gathered back and discussed our viewpoints together. More brains are better than one. Sometimes, from one idea, many other ideas sprung up or the idea was improved based upon comments. Disagreements also occurred. But as a team, we clarified on the ideas, evaluated them and decided on the best ones for the final design.” (student I)

Configurations of information space of problem

As for the second part of the reflection journal trigger, students found the scope of the information search for the given problem to be wide in ambit and challenging. Being an ill-structured design problem, it was not possible to agree upon a definitive solution and thus, there were no standardized right or wrong answers. Typically, tackling an ill-structured problem involves consideration of a myriad of plausible ideas that are evaluated based upon a set of criteria to build a coherent design solution. A few constraints were stated in the problem statement but the goals were nebulous and the information demands indeterminate or not clearly defined. There were no established existing archetypal architectural design specifications that students could refer to as guidelines in framing potential solutions. Thus, it was hardly surprising when students prevalently commented that they were not sure even on how

they should commence their information search and what appropriate search terms they ought to enter to execute search actions. Since students were not adequately trained in the rigours of information search skills, they couldn't effectively process the information needs of the multi-faceted design problem from various analytical perspectives. Ill-structured problems are complex and dynamic in design and require an information search approach that encompasses different angles of reasoning and exploration. Hence, students couldn't formulate an information action plan that would inform them on the procedures and strategies they could adopt in implementing their search activities to access needed information. Thus, many students faced difficulties and experienced setbacks in performing their information search and solving of the given problem. Enclosed are some sample excerpts from students' inputs that support the argument that students lacked sound information searching abilities and needed further training:

"We tried hard but found rather scarce related information on the net. The Internet research did not help much!" (student C)

"We first searched the Internet on the differences between escalator and travelator. When we confirmed them to be different, we decided to put in our solution. We tried to search for building construction sites but couldn't find any relevant information. Thus we had to solve the problem by relying on prior knowledge and real-life examples we have read up before." (student L)

"The problem question was written such that it is not possible to copy an existing transportation system elsewhere in the world. There were lots of factors to be concerned about e.g safety of passengers etc. We search hard

on the Internet for information by looking for different types of transportation. Some of our team members tried to even do a search under 'future transportation.' But it all didn't help us much." (student M)

Lack of information planning

Even when the information search was successful and unearthed relevant information, this happened fortuitously or incidentally rather than due to consciously planned and executed search activities. For example, student Y remarked that "to search for information we looked up on the net because that is the easiest way to look for information.....we accidentally found out about the burj tower which is going to be up by 2008." These findings give credence to one of the main research propositions of this study - students need to be methodically trained in skilled Internet information searching and be made aware of the range of scaffolding search strategies.

Only a few of the participant students seemed to have had some measure of success in excavating relevant information from the Internet morass. For example, student X expressed that "since none of us was sure what a skyscraper was we carried out research to find out more to build our dream tower. We did find the Taipei 101 (which is in Taiwan and was completed in 2004) and Burj (to be completed in 2004). They acted as our guide and reference. After that we carried out research on the different ways of transportation and came across a lot of useful facts." Student Z wrote that "to search for relevant information, we looked up on the net since it is the easiest way to look for information and we knew information would be there in

the websites.....we did use the Internet to find out more on how submarines work and other methods instead of the use of lifts.”

Even amongst this minority of students, the focus of their search efforts often digressed to locating pictures rather than abstracting and processing valid factual content. Students failed to realize that pictures only have an enhancing effect on the quality of their presentations and that substantivity in subject matter is what that is more important. Corroborating this conclusion are the following pertinent comments by student X: “We spent quite a bit of time searching through the Internet for pictures on skyscrapers.....” This analysis was significant in confirming the recurrent theme encountered in this study – theoretically, students were well aware of the wealth and ready availability of information hosted by the Internet but struggled to adopt the right strategies in efficiently burrowing their way through the convoluted networks of information to access the right resources. This once again underscores that students’ information search literacy competencies can at best be described as rudimentary and further development through systematic instructional scaffolding was necessary.

CHAPTER 5: INTERVENTION

A skills-based training intervention was conducted to determine the treatment effects of different Internet information searching skills and strategies on students' abilities to solve different types of problems. The empirical evaluation of the efficacy of this intervention was based upon the analysis of the impact of these information searching skills on outcomes of problem solving. This resulted in a set of heuristics that inform teachers, educational planners and instructional designers about the nature of the relationship between different information searching techniques and problem types.

The building blocks of this analytical training framework are predicated on the conceptual ideas of Eagleton, Guinee & Langlais (2003), Jakes, Pennington & Knodle (2002), Spink (2003) and Nachiamas & Gilad (2002). The framework serves as a flexible structure of reference and consists of a suite of recursive Internet information searching strategies that equip students with the necessary information literacy skills to enhance their problem solving capabilities. The recursive nature of development of these information searching skills needs to be emphasized since Internet navigational and information searching activities are non-linearly ordered and dynamic.

The design of this framework was primarily based upon an inquiry-based learning approach that calls upon a variety of critical skills such as logical reasoning and reflective thinking. Inquiry-based learning promotes learning experiences enabling the exploration of theoretical ideas and conceptual change (Teixeira-Dias, De Jesus, de Souza, & Watts, 2005). The investigative questions posed by students in inquiry-based learning help students to organize their exploratory ideas, increase students' levels of learning engagement and foster interactional collaboration between teachers and students. .

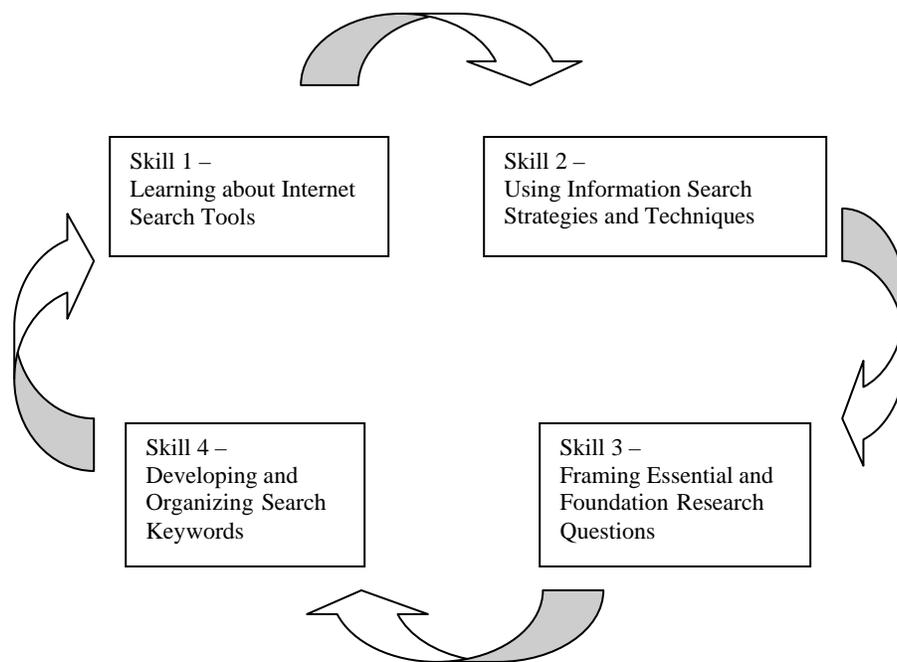


Figure 15: Training interventionist framework schema

Skill 1 (Phase 1) – Learning about Internet search tools

The first skill articulated in the training framework required students to methodically learn about the various types of information search tools found in the Internet. If the websites from which needed information could be abstracted is known, then the URLs of these specific portals could be directly keyed in to access them. More often than not, it is near impossible for students to know the URLs of all relevant websites to be able to apply this direct access strategy since information needs are diverse. Hence, they were given training on effectively using the two classes of Internet search tools - search engines and search directories.

Students were first informed on the mechanisms of search engine operations involving automated spiders. They were next directed to explore major, popular search engines such as Google, Alta Vista, WebCrawler and Lycos to learn more on these search engines and their advanced search features. Since search engines work in different ways to create a niche market for themselves, the strengths and limitations of these search engines in terms of their search roles, functionalities and capabilities were highlighted to students for their awareness.

Students were then familiarized with meta-search engines. They were cautioned that though meta-search engines combine the search power of different search engines, this doesn't necessarily mean that meta-search engines necessarily outperform regular search engines in producing more precise search results. They were also told that meta-search engines generally use the most basic level searching protocols and so don't allow for

refinement of searches in sophisticated ways. However, meta-search engines do afford opportunities for cross-referencing and making effective comparisons between the search output of regular search engines and meta-search engines for the same query. Students were encouraged to try using meta-search engines and evaluate their information searching capabilities. Some examples of major meta-search engines that were recommended to them were Dogpile and Mamma. It was also highlighted that meta-search engines do not of their own parse through databases but transmit their searches simultaneously to several individual search engines to scan the databases of these search engines and present integrated web search listings (Sherman, 2005).

Having been exposed to the working dynamics of search and meta-search engines, students were then acquainted with the next set of search tools - search directories. It was pointed out that search directories are powered by inputs from human editors and so have a higher degree of reliability in their search output when compared to search engines. However, it was brought to their attention that results listings may not be comprehensive due to limitations imposed by the dependency on human efforts in compiling the databases. Students were referred to popular search directories such as Yahoo!, Snap and DMOZ to experientially explore them for their search applicability (Sullivan, 2002).

In summary, during this first phase of the intervention, students were informed on the working attributes and operational mechanisms of search engines and directories. This was an important component of the training

since a predominant majority of students provided feedback in the pre-intervention survey and reflection journal entries that they were not fully aware of the range of available Internet search tools. In fact, some of the essential differences between search directories and search engines are often misunderstood even amongst adult Internet users (McGuire, Stillborne, McAdams and Hyatt, 2002). Hence, students were acquainted with the purpose-specific uses of search engines and directories to become conversant with the functional purposes of these two main types of search tools and utilize them effectively.

Skill 2 (Phase 2) – Using information search strategies and techniques

Having introduced students to the search tools offered by the Internet, they were then oriented to Internet information search strategies and techniques that facilitate efficient information seeking. This was accomplished by familiarizing students with the goals and uses of the different strategies and then providing students with hands-on opportunities to exploratively try them out in their search practices. Thus, mixed modalities of learning combining information dissemination and self-directed experiential learning were utilized to implement this phase of the training intervention. Creating awareness of and providing information on a broad gamut of strategies was meant to be an effective means of direct instructional mediation in raising students' information search proficiencies and the practice session afforded opportunities for students to apply what they have learnt in situated contexts.

One useful search strategy suggested to students was that of using multiple search engines, including metasearch engines during their information

searching activities. Students are normally inclined to access a single search engine for all their information needs. Since search engines usually function in distinct ways and present search results that vary for the same query entered, students were cautioned against reliance on a single search engine. Instead they were encouraged to seek multiple search engines and their advanced search features to carry out their information search. As participant students' search term crafting skills were not fully developed, they were instructed to repeat the same query with different search engines in locating information sources and verifying the authenticity of desired information through cross-referencing.

Students were advised to try the following heuristics in guiding their initial attempts at trying to put into practice what they had learnt thus far on Internet search tools. Since the Web contains billions of pages, they were told to begin their search with Yahoo! since it has a relatively manageable directory of fairly high quality and reliable web sites. If they found the search to be unsuccessful, then it was suggested to them to try Dogpile, a common metasearch engine. Dogpile allows users to choose the search engines they prefer the search to run under and the search is simultaneously transmitted out to the search engines with results presented separated according to the different search engines. If students were still unable to locate the necessary resources, then they were told to access AltaVista as it has the largest and most comprehensive database of indexes. AltaVista was recommended as the last choice in this search route since the less competent students might

become overwhelmed by the power of the massive database of indexes afforded by this search engine.

Students were then familiarized with the next set of information search strategies from Nachiamas and Gilad's (2002) taxonomy explicated in the literature review section of this dissertation - direct keyword search, wide search definition, complex search strategy, use of general knowledge and computer conventions involving file suffixes such as *.gif* and *.jpg*. The example of the search task on finding a picture of Mona Lisa as described in Table 2 of the literature review chapter was used in elucidating the application and utility of these strategies in information seeking.

Having instructed students on the essentials of search strategies and encouraging them to explore these strategies, they were next introduced to useful search techniques that complement search strategies. Capitalizing upon these techniques ensures that search engines yield manageable lists of relevant search results. Some key search techniques that students were acquainted with included the following:

Searching for an exact phrase. The first simple but effective technique that was taught was that of specifying the search phrase surrounded by double quotes to find an exact phrase in the document results listed by a search engine. The search engine then initiates a search for websites with the entered sequence of words in the order as typed in. This example was provided to students to explain this principle: Entering "giants baseball" returns listings where the words "giants" and "baseball" appear together and in that

order either in the title, the URL of the website, the description or the document.

Searching for required, excluded and multiple words. Students were then educated on the utility of the following Boolean searching operators, either “simplified Boolean” (using pluses and minuses) or “full” Boolean (AND, OR, NOT):

- (1) Typing the plus sign (+) or the word AND specifies that both words be present in the displayed results (Hock, 2001). This example was given to illustrate this point: typing in *giants + baseball* or *giants AND baseball* retrieves only those pages where both the words “giants” and “baseball” are present on the same page.
- (2) Using the minus sign (-) or the word NOT ensures that a word is excluded from the search results. The following example was presented to explain this concept: *giants - baseball* or *giants NOT baseball* generates web pages that have the word “giants” but not the word “baseball” in them.
- (3) Using the word OR in the search phrase instructs the search engine to list those web pages that have either of the stipulated terms. For example, *giants OR baseball* produces those pages containing either “giants” or “baseball” in them.

Being specific. Another useful search technique that was shared with students was that of being specific when defining keyword search terms (Eagleton & Guine, 2002). Using specific search phrases enables more narrowed down search results listings to be presented. Entering a broad term such as ‘basketball’ to find out who was the inventor of basketball was shown as a demonstrated example of poor search term crafting. Instead, students

were advised to modify the search phrase by adding in “inventor” to enter in the search query of *basketball + inventor*.

Being exact. The next keyword search technique that was highlighted to students was that of being exact in framing keywords (Eagleton & Guine, 2002). This example was provided to elucidate on this point: To find the name of the US president who got stuck in a bathtub, using the phrase “president stuck in bathtub” wouldn’t be successful since this exact phrase is unlikely to appear on a web page. Instead trying a search phrase as *president + bathtub + stuck* might be more successful in engineering a successful search.

Being distinct. Another useful rule that was communicated to students was the importance of being direct and focused in executing their searches. Students are generally inclined towards adding in more terms than necessary in their keyword phrases since they believe that inserting more words enhances the search (Eagleton & Guine, 2002). Student participants were instead encouraged to focus on one search at a time within a specific area to improve the focus of the search. For instance when one wants to explore on Australia, he/she will not be too successful if too many unrelated terms are entered -*Australia + money + food + language + sport*. It was suggested that it would be better to restrain the search to one sub-topic at a time (*Australia + languages*). If a search project looks at multiple areas of focus, each topic can be searched for separately as independent queries.

Being succinct and concise. Finally, students were advised to be succinct and concise in their choice of keywords and eliminate unnecessary words (Eagleton & Guine, 2002). The following example was highlighted to

them to demonstrate the application of this principle: One who wishes to know what year George Orwell's book "Animal farm" was published may try searching for the entire question ("*What year was George Orwell's book Animal Farm published*"), a phrase ("*George Orwell's book Animal Farm*"), or a sentence fragment ("*year Animal Farm published*"). However, this may not directly yield the specific information sought after. It would be preferable to try the search phrase containing the key terms ("*George Orwell*" + "*Animal Farm*" + *published*). Students were cautioned that good search terms need not necessarily come from the research questions. Potential substitute search terms sometimes need to be tried. The following example was used to illustrate this point: Based on the research question "How much money does Nomar Garciaparra make a year?", a novice searcher might use the following search terms "*Nomar Garciaparra*" + "*money he makes a year*". However, the phrase "*money he makes a year*" is too generic and should be replaced with the search word *salary* for a more focused search ("*Nomar Garciaparra*" + *salary*).

Skill 3 (Phase 3) – Framing essential and foundation research questions

An inquiry-based instructional approach is an integral aspect of problem solving. Inquiry-based learning is a process where students formulate investigative questions, obtain factual information and then build knowledge that reflects their answer to the original question (Jakes, Pennington and Knodle, 2002). Such a process also facilitates the development of a pool of relevant keywords to initiate fruitful Internet information searching. It has been shown that the majority of students who are unsuccessful in problem solving

do not model effective search plans that guide their search activities. When they access the Internet in search of information, the last thing that an expert navigator would do is the first thing they perform i.e. head straight to a personally preferred choice of search engine and type some simple keywords, resulting in a deluge of irrelevant hits (McGuire, Stillborne, McAdams and Hyatt, 2002).

Acquainting students with an inquiry-based pedagogical orientation becomes critical in the context of successful information acquisition and problem solving. This begins with the pivotal step of teaching students how to frame essential questions – the kinds of probing inquiries which make a difference in the quality of learning – investigations that cast light in dark corners, illuminating unknown truths. Jakes et al (2002) have elaborated that essential questions are those that require students to make viable decisions or plan courses of action based upon sound reasoning. Essential questions are the starting point of a search attempt and they frame the search process. Formulation of student authored essential questions is a vital component of structured inquiry and marks a departure from traditional classroom modes of interactions predominated by teacher talk.

Students were, however, reminded on the onset of this phase of the intervention training that just not any type of routine questions can be accepted as essential questions. “What is” questions generally can’t be accepted as essential questions since such questions don’t induce students to enquire and think deeply. One example of a “what is” question that was discussed with students was “*What is cancer?*”. Such questions lack focus and

are too broad in scope to enable an effective search to be carried out. They license plagiarizing by allowing chunks of information to be cut and pasted from websites without investing critical thinking into devising a developmental action plan.

After informing students on some of the broad definitions of what constitutes meaningful essential questions, participant students were next acquainted with the following useful attributes of good essential questions (McKenzie, 1996) to help them in crafting essential questions:

- Essential questions reside at the top of Bloom's Taxonomy (Bloom, 1954). They require students to evaluate (make a thoughtful choice between options, with the choice based upon clearly stated criteria), to synthesize (invent a new or different version) or to analyze (develop a thorough and complex understanding through skillful questioning).
- Essential questions invoke our curiosity and motivate us to want to understand issues at a deeper level.
- Essential questions warrant exploration and research. The answers to these questions are not run-of-the-mill types but require students' active construction of independent responses through meaning-making and thoughtful interpretations.
- Answers to essential questions cannot be found instantaneously but takes time and is a progressive inductive process.
- Essential questions engage students in real life problem-solving applications.

- Essential questions usually lend themselves well to inquiry that is multidisciplinary in character.

Since participant students in this study were generally novices in framing essential questions on their own, they needed instructional guidance in the development of these skills. Hence, students were presented with numerous examples of challenging teacher-generated essential questions to familiarize them with the process of essential questions crafting. The following sample good essential questions by Jakes et al. (2002) and McKenzie (1996) were distributed to students and the rationale as to why these are good essential questions was explained to students to further their understanding:

- How can I develop a plan to reduce the chances of contracting cancer in one's lifetime?
- Should Puerto Rico become the 51st state of the United States?
- How could technologies be used to improve teaching and learning?
- What invention of the 20th Century has had the greatest impact?
- Is there parity in the justice administered by the judiciary system of Singapore?
- What are some good administrative policies you would recommend in policing the use of Internet within school premises? Present your arguments by comparing current policies in place in other schools in the country.
- What do you think are some of the greatest risks associated with students indulging in CD-Rom edutainment products? What evidence could you find to dispute or validate fears of adults on this issue?

After understanding how essential questions are formulated, crafting of foundation questions was then taught to students. McKenzie (1996) alternatively labels foundation questions as subsidiary questions. Foundation or subsidiary questions, as the names suggest, provide students with the scaffolding structures in working towards and achieving the search objectives conveyed by the essential question. The answers to foundation questions generate substantive information which then can be processed and integrated to build up coherent solutions in response to the essential question (Jakes et al., 2002). Foundation questions aid students in better structuring their search pursuits by breaking down the essential question to be investigated into its constituent components. This allows students to cognitively model networks of epistemic relationships and associative links within nested structures, with the essential question as parent question being conceptually connected to secondary foundation questions.

Students were informed that developing about 6-10 foundation questions for each essential question should be reasonably sufficient. For a topical essential question such as “*Should the wetland areas in the USA be preserved?*”, possible foundation questions that could be generated include “*What is a wetland?*”, “*What are the reasons for saving wetlands?*”, “*Why are wetlands being destroyed?*”, “*Who is destroying wetlands?*”, “*How many acres of wetlands exist in the USA?*”, “*At what rate are wetlands being destroyed?*” and “*What are the best methods for saving wetlands?*”. Students were reminded that the exact number of foundation questions to be formulated,

though, is contingent upon the intellectual complexity of the essential question and the problem solving requirements of the given task.

Varied worked examples as cognitive aids were presented to students to model the techniques of generating foundation questions. A worked example is a step-by-step demonstration of how to solve a problem or perform a task. Worked examples are one of the most powerful instructional methods for building new and rich knowledge representations in long-term memory (Clark & Mayer, 2003).

The worked example sessions during the intervention training were purposefully designed to ensure that they were student-centered, yet done in consultation with the facilitator - allowing both the facilitator and students to actively co-brainstorm ideas and list down different categories of relevant questions on the fly. Instructional mediation from the facilitator was crucial since students lacked prior experience in independently authoring foundation questions. The facilitator actively monitored students in their efforts at developing foundation questions, assessed the relevancy of these questions and provided timely diagnostic feedback to students when needed. Normally, butcher papers or graphical organizing software are used in recording these questions when they are raised and discussed spontaneously during class interactions. However, as suggested by McKenzie (1997), Inspiration, a powerful and user-friendly graphical organizing program was used in this study. Inspiration affords ease of movement, with questions being conveniently shifted around on screen to be organized for better coherence and visual clarity. Such an emergent approach promotes collaborative

dialogue and synergy in generating meaningful questions. The following is one illustrative example of an essential question trigger that was posed for discussion during the intervention in coaching students to become conversant with developing appropriate foundation questions:

What are the key issues associated with students' use of e-mail in schools?

The facilitator began the working session with an online demonstration familiarizing participant students with the basic features and tools of Inspiration. Students' laptops were loaded with Inspiration software to simultaneously try out the actions being projected on the screen. Collectively, the facilitator together with the students discussed and listed all the foundation questions they could think of in relation to the given essential question. The facilitator-researcher documented these questions in the outlining component of Inspiration, an example of which is shown below. Inspiration has the built-in capacity to convert this outline into cluster diagrams consisting of node and link network representations that could later be moved around and edited accordingly.

What are the issues associated with students' use of email in school?

What are the potential benefits?

Educational?

Social?

Entertainment?

What are some inherent problems?

What are the school regulative policies to be implemented?

What are the available hardware resources?

Are the resources sufficient?

Is there a need for additional resources?

What are the costs involved?

What is the role of stakeholders?

Teachers?

Parents?

School management?

Alumni?

Ministry of Education?

How to train students?

Should an external training vendor be engaged?

What are the timing schedules and costs involved?

What are good practices models to be referred to?

How and who ought to evaluate learning progress?

This outline was then transformed by Inspiration into the following cluster diagram:

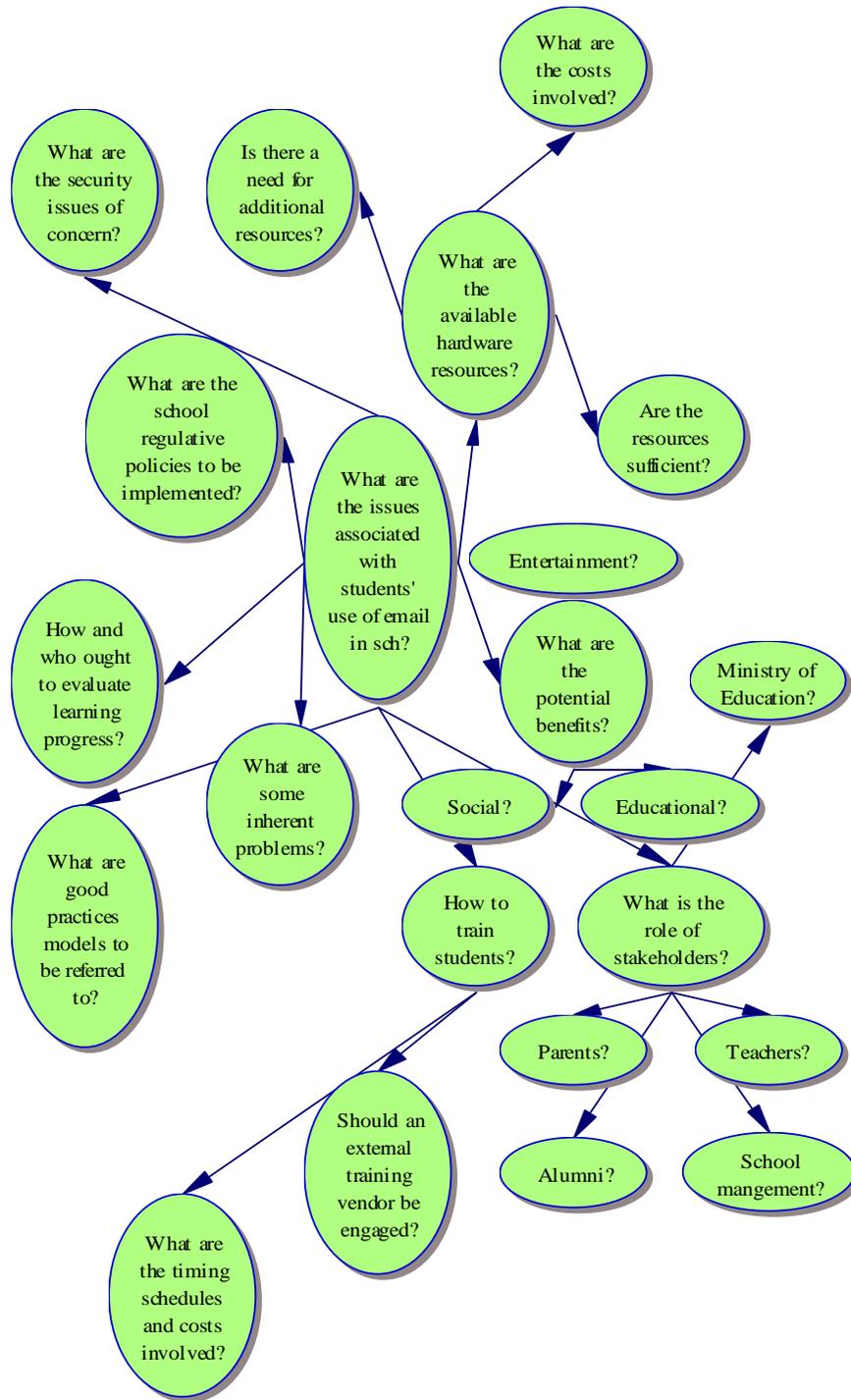


Figure 16: Inspiration produced cluster diagram

Besides worked problem examples, practice problems are necessary to improve learning since worked problems alone do not afford sufficient opportunities for meaningful reflection on learning goals, performance and progress. Practice problems, on the other hand, serve to bridge the gap between theory and praxis. The psychological advantage of including task-oriented practice problems is that these problems provide multiple overt rehearsal opportunities for encoding in long-term memory (Clark & Mayer, 2003). Overall, the combination of worked examples and practice within an instructional framework enables the activation of learners' prior knowledge and facilitates the acquisition of a broad range of problem schemas (Jonassen, 1997).

At the end of phase 3 of the intervention, students were required to collaboratively attempt hands-on a practice problem task in groups of five. Such an exercise allowed both the students and facilitator to monitor and determine students' learning progress in effectively framing essential and foundation questions. Students had to submit the Inspiration-authored artifacts they had created and these were collected for analysis since they served as rich sources of data in assessing students' problem solving performances. The following was the problem-solving task that was given to students and they were required to develop relevant essential and foundation questions:

With the economy becoming increasingly global in outlook, patterns of family movements to different regions and countries is becoming increasingly prevalent. Your family had to move overseas due to work commitments and a desire for better quality of life. You need to persuasively recommend to your parents the best choice of a city to move to given the options of Kuala Lumpur, Beijing and Sydney. Explain your comparative choice with reference to a set of criteria measurements.

The artifacts produced by students in response to the requirements of the given practice task was qualitatively assessed according to the criteria explained in Chapter 3 of this thesis. Examination of the submitted artifacts demonstrated that the objectives set out for this phase of the intervention have been adequately met. Students had developed a good understanding of the techniques of essential and foundation questions crafting. These questions functioned as the anchors around which the information searching process could be modeled in finding information and accomplishing problem solving. The submitted artifacts showed that students had realized the need to thoroughly investigate the information needs of a problem from a variety of analytical angles before executing information searching.

Results

The essential question developed by Team A was “*Which is the best choice of city to move to?*”. The first foundation question crafted by this group of students was “*What is the climate like?*” with the sub-foundation questions being “*Is it similar to Singapore?*” and “*Are there changing seasons?*”. The second foundation question that was framed was “*Can we adapt to the new*

society?” with the sub-foundation questions being “How is the education system like?”, “Can we adapt to their food and eating styles?”, “What are their cultures and languages spoken?”. The next four foundation questions posed by this team were “What is the political system and security like?”, “What is the economy like?”, “How developed is the country?” and “How suitable is the entertainment?”. Team A’s final foundation question was “What is the quality of life and the standard of living?” and the sub-foundation questions branching out of this question were “What is the cost of living?”, “How convenient is transportation?” and “How close is the workplace?”.

Team B’s essential foundation was *“What are the factors to consider in choosing to move to another country?”*. The first few foundation questions framed by students in this team were *“What is the culture of the new country?”, “What is the cost of living in the new country?”, “What are the costs involved in moving to the new country?”* and *“Which country is nearer to Singapore?”*. The next foundation question of Team B’s was *“What are the languages used in the new country?”* with the sub-foundations being *“Do we know their languages?”, “Are they difficult to learn?”* and *“Are there courses available to learn the languages?”*. This was followed by another foundation question *“How good are the living conditions in the new country?”* with the sub-foundation questions being *“How is the education system?”* and *“How are the health services?”*. The next foundation question crafted by students in Team B was *“What is the environment like in the new country?”* and the sub-foundation questions stemming out of this question were *“Are there seasons in the new country?”* and *“Are there natural disasters?”* The team’s final

foundation question was *“How is the transportation in the new country?”*.

Related sub-foundation questions for this question were *“What are the kinds of transportation offered?”*, *“Are cars expensive?”* and *“How much does it cost to take a train?”*.

The essential question articulated by Team C was *“What are the factors to be considered in moving?”*. The first foundation question posed by this team was *“What is the quality of life?”* and the sub-foundation questions arising out of this question were *“How are the weather conditions?”*, *“Is there social cohesion?”* and *“What are the standards and costs of living?”*. Team C’s second and third foundation questions were *“How far is the country from Singapore?”* and *“How good is the transportation?”*. The fourth foundation question that was framed was *“Is the educational system good?”* with the sub-foundation questions being *“Is education easily accessible to us?”*, *“What are the costs of schooling?”*. The next few foundation questions advanced by students were *“How stable is the economy?”*, *“What are job prospects like?”*, *“How good and what are the costs of health services?”*. Team C’s last foundation question was *“How stable is the country politically?”* and the secondary foundation questions that came out of this key question were *“How good is the government in handling the country?”*, *“Is there racism around?”* and *“Is the country being terrorized?”*.

Team D came up with the essential question of *“What is the best choice of city to move to with my family?”*. It’s first foundation question was *“What is the security like?”* and the sub-foundation questions were *“What are the laws and regulations?”*, *“What are the crime rates like?”*, *“What security measures*

are taken to curb crimes?". The second foundation question was "*How far are the distances?*" with the sub-foundation questions being "*How long does it take to travel around in the country?*", "*How far is the country from Singapore?*". The third foundation question framed by the students in Team C was "*What jobs are there?*" and the foundation questions originating out of this question were "*What kinds of jobs are there?*", "*What are the experiences needed for these jobs?*" and "*What is the average pay?*". Team D's fourth foundation question was "*What is the education system like?*" with the secondary foundation questions being "*What are the educational standard and facilities?*" and "*What are the languages used in school?*". The final foundation question that was crafted was "*What are the standard living conditions and is it adaptable?*". The sub-foundation questions proposed for this question were "*What is the cost of living?*", "*How good and what are the costs of transportation available?*", "*How are the people there like?*" and "*What is the culture of the people?*".

Team E formulated "*What are the factors to be considered in moving?*" as their essential question. The first few important foundation questions students in this team developed were "*How good are education services?*", "*What are the standards and quality of life?*", "*How far is the new country from Singapore?*" and "*How are the weather conditions?*". The next foundation question that was defined by Team E's students was "*How good is the transport?*" with the sub-foundation questions being "*How convenient is public transport?*". The next foundation question was "*How is the government?*" and related sub-foundation question were "*How is the political stability?*" and "*How*

is the political security?. The final foundation question framed by Team E was “*How is the working environment?*”. Associated sub-foundation questions were “*Can we get jobs fast?*” and “*How good is it to do business?*” and “*Can we get jobs fast?*”.

Discussion

All five groups of students came up with relevant essential questions that were well aligned with the information demands of the problem and focused on making an evidence-based decision on the choice of city to migrate to.

One relevant foundation question that was commonly found in all five teams’ products was on finding out more on the standard living of the city of choice. This is indeed an important question to be examined since quality of lifestyle is a vital topical factor to be researched on in order to reliably determine the degree of likeability of a potential new city of residence. Students reasoned that the standard of everyday living offered by a particular city is a compelling concern – one that profoundly impacts the migrant at both individual and family unit levels.

Another appropriate concern expressed by all five groups was on ascertaining the quality of educational systems and facilities available in the 3 cities. Some of the students explained that this factor was of major concern to them. Being tertiary students, education was a fundamental issue that was close to their hearts and one that they could easily identify with due to their many years of prior learning experiences. Singapore’s education system is global in its orientation and constantly reinvents itself in light of changing

economic and industrial demands. Hence, these students have encountered pedagogical and curricular paradigm shifts at one time or another during the span of their learning careers. So, students, not surprisingly had given much thought to this issue on reviewing the quality of education available in the new cities.

Another area that students from the five groups identified to be of importance in making a choice between the 3 cities was the quality of transport access in these cities. Students noted that their research has to be comprehensive enough in finding out more on conveniences of public transport and affordability of private vehicle ownership schemes in these cities. Many students remarked that they had regularly heard of or seen in media numerous transport related problems plaguing major metropolitan cities. Some of these problems include convoluted road network systems, appalling traffic jams, crowded public transport facilities, difficulties in accessing public transport, limited hours of operation of public transport systems, soaring road taxes and car prices. Hence, this issue on the standards of transport systems was of importance to students since it had a direct impact on overall convenience in getting around in the city. One ingenious team even suggested that the availability and costs of alternative kinds of transport modes besides traditional cars, trains and buses had to be explored in deciding on the choice between the three cities.

Four groups – teams A, B, C and E rightly wanted to research more on the environmental climatic conditions of the 3 cities being evaluated. Due to its rather ideal geographical location, the climatic conditions in tropical Singapore

are largely constant, with the weather generally being humid and sunny throughout the year. This is unlike many other major cities in the world that are significantly affected by widely fluctuating seasonal environments, with extreme weather conditions at times even disrupting normal everyday functioning. Students having been accustomed to local stable weather conditions preferred their choice of city of migration to not be subjected to the vagaries of weather.

Teams A, C, D and E wanted to investigate more on economic stability and job prospects. This is indeed a critical consideration that significantly impacts a family intending to shift to another location. The economic clout wielded by the new city of residence directly correlates to the level of financial security and quality of lifestyle family members can potentially enjoy. This is also tied to the depth of purchasing power and type of social status entitled to the family. Employment prospects and the amounts of income earnable directly impact the degree of affordability and sustainability in managing costs of living and meeting the necessary essentialities of life.

Three teams, A, C and E judiciously noted the need to examine the political situations in the 3 cities being reviewed for their suitability to move to. Political stability is important for the efficient functioning of the country's judiciary and the government's ability to maintain peace in the country. Thus, students rightly assessed that the stability of the political situation prevailing in a city is a key factor in weighing the possibilities of moving to the city. Students in these teams felt that having been used to the durability and steadfastness of the system of governance in Singapore, which by and large insures the

mass of its population from political chaos and social bedlam, moving to another city that similarly enjoys a high level of political stability, social cohesion and orderliness in administration was of paramount importance.

Another legitimate consideration that warrants further scrutiny is the proximity of the three cities being assessed for migration to Singapore.

However, quite surprisingly, this was a conspicuous omission in two of the groups' submitted artifacts. Only teams C, D and E had explored this issue.

For obvious practical as well as economic reasons, distance would have been a tangible priority in the matrix of factors to be considered in the selection of a prospective city of migration. Students from teams C and D offered the explanation that there is the added psychological impetus in wanting to move to a city that is nearer to Singapore since it would feel 'closer to being home'.

Surprisingly, only teams B and C mentioned healthcare costs as a concern during their brainstorming. Singaporeans have had to grapple with spiraling healthcare and medical costs and this is a common complaint amongst many Singaporeans. Hence, it was expected that most of the participant students, if not all of them, would have raised this issue in their discussions. However, three of the teams had overlooked this consideration.

Interestingly, team A entered a foundation question on the quality, suitability and types of entertainment available in the 3 cities being reviewed. When queried, some of the team members explained that due to political pressures or religious directives certain cities or their parent countries impose restrictions on entertainment freedoms. Though not exactly an issue of critical concern, the fact that students had tried to approach the given problem from

this perspective of analysis sufficiently demonstrated that the practice session on developing good questioning skills had provided students with opportunities to cultivate and exercise innovative thinking.

Skill 4 (Phase 4) – Developing and organizing search keywords

After students had learnt to model the questioning process, the next and final stage in the intervention framework was the training of students to initiate an action plan to seek answers to the brainstormed essential and foundation questions. Two primary instructional strategies that students could possibly adopt during this stage of the intervention were scavenger hunts and keyword-category concept maps. Scavenger hunts could independently be designed or existing scavenger hunts such as www.yahooligans.com could be leveraged upon in carrying out information searching exploration. Keyword-category concept maps could also be used for both individual and group work where students generate and organize keywords for each research question before actually embarking upon information seeking (Eagleton, Guinee & Langlais, 2003).

For the intervention training of this study, keyword-category concept maps were preferred over the option of scavenger hunts. Scavenger hunts are structured activities in which the teacher closely monitors developmental progress. Scavenger hunts have clear boundaries with very specific information goals being met. Thus, scavenger hunts are more suited for younger primary school students with little or no prior Internet information searching experiences. Since the students involved in this study are older, first year polytechnic students, endowed with better cognitive capabilities, it was

determined that keyword-category maps would be a better technique to employ in training students during this stage of the intervention. Keyword-category concept maps are better aligned towards tackling multi-disciplinary, information-oriented problem solving research projects.

This fourth stage of the intervention was designed to provide intensive instructions and guided practice to students in training them to efficiently develop keyword-category concept maps after carefully selecting a pool of relevant keywords. This ensured that students do not prematurely focus on content acquisition or the final products to be submitted. Concept maps as graphical representations of knowledge comprise of concepts and the relationships between them (Novak & Govin, 1984). Consisting of labeled nodes and links, they are useful pedagogical devices that allow students to acquire knowledge quickly and in non-linear ways than that afforded by traditional teaching methods such as simple keyword listing (McNaught & Kennedy, 1997). Keyword-category concept maps could effectively be used by students in promoting the organized development of conceptual and associative understandings. Keyword-category concept maps could be either teacher or students prepared templates with blank bubbles or boxes for students to insert in keywords for topic and focus areas.

In attempting to equip participant students with competent keywords crafting and organization skills, the objective of this stage of the intervention was to educate students on the techniques of keyword-category concept mapping. Eagleton, Guinee and Langlais (2003) have cognitively modeled the process of constructing key-category maps by examining a subject topic in

terms of component items such as theme, topic, focus and questions. This study has applied the ideas they have advocated. The theme refers to the broad agenda of the information exploration to be performed and is drawn from the objectives of the essential question. Topic and focus areas are the specific domains of search interest and can directly be linked to each foundation question. The topic and focus inputs then become the keywords for information searching to be accomplished. Pre-prepared examples of keyword-category concept maps such as the following one were then shown to students to demonstrate how keyword-category concept mapping can be done.

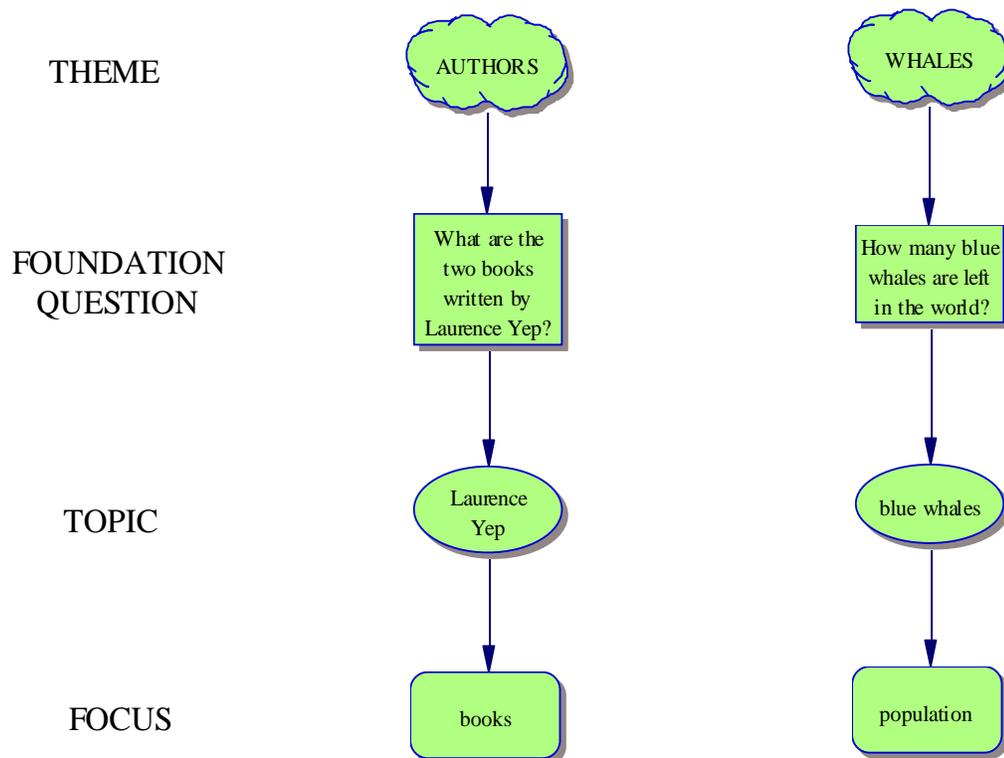


Figure 18: One example of keyword-category concept map

Then, students were engaged in guided practice where they were instructed to select 6-8 of the foundation questions they had developed as part

of the requirement for the task assigned in the earlier phase 3 of the intervention. For each of these questions, students in their designated teams had to collaboratively construct keyword-category concept maps to create a pool of potential keywords that could be entered in search engines to seek information in response to the formulated questions. The facilitator was available in class during the practice sessions to offer assistance and to attend to doubts or queries. Students were required as part of ongoing formative assessment to submit in the keyword-category concept maps they had developed during the practice session.

Results

The following tables encapsulate the keywords each team of students had selected from their foundation questions for theme, topic and focus areas in developing keyword category maps:

Tables 6-10 : Teams' theme, topic and focus areas

Team A

Theme	Topic	Focus
Migration	Climate	Weather, Seasons
Migration	Adaptability	Food, Culture, Education, Languages
Migration	Political System	Security
Migration	Economy	Stability
Migration	Development	Infrastructure, Technology
Migration	Entertainment	Suitability
Migration	Living Standards	Convenience, Cost of Living, Workplace Environment

Team B

Theme	Topic	Focus
Migration	Culture	Arts, Traditions
Migration	Cost of Living	Expenses
Migration	Moving	Costs, Distance
Migration	Languages	Familiarity, Difficulty, Courses
Migration	Living Conditions	Education, Health Services
Migration	Environment	Seasons, Natural Disasters
Migration	Transportation	Types, Costs
Migration		

Team C

Theme	Topic	Focus
Migration	Living Quality	Weather, Social Cohesion, Costs
Migration	Closeness	Distance
Migration	Transportation	Convenience, Accessibility
Migration	Education	Accessibility, Costs
Migration	Economy	Stability, Impact
Migration	Job Prospects	Business Opportunities, Working Conditions, Jobs Availability
Migration	Health Services	Costs, Accessibility
Migration	Stability	Politics, Racism, Terrorism

Team D

Theme	Topic	Focus
Migration	Security	Laws, Crime Rates
Migration	Distance	Routes, Times
Migration	Jobs	Types, Previous Experiences, Qualifications
Migration	Education	Syllabus, Languages, Facilities
Migration	Standard of Living	Transportation, Economy, Culture
Migration	Transportation	Accessibility, Types Available

Team E

Theme	Topic	Focus
Migration	Education	Quality, Costs
Migration	Quality of Life	Cost of Living, Living Environment
Migration	Distance	Proximity
Migration	Weather	Fluctuation
Migration	Transport	Convenience
Migration	Government	Political Stability, Political Security
Migration	Job Prospects	Working Environment, Business

Discussion

Evaluation of submitted artifacts showed that generally all five groups of students performed credibly well in identifying appropriate keywords and organizing them within schematic concept maps. For instance, Team E in relation to the foundation question of “*How good are education services?*” rightly selected *education* as the keyword for topic and *costs* and *quality* as the keywords for focus areas. On the topic of *culture*, students from Team B correctly recognized *traditions* and *arts* as central keywords to be focused upon in searching for information on the Net. For the foundation question on how safe the city is to live in students from Team D fittingly identified *security* as the keyword for topic and *laws* and *crime rates* as the core keywords of focus. Another good example was Team C who relevantly suggested *health services* as the keywords for topic and *costs* and *accessibility* as the keywords for the search focus in seeking answers to the question on the level of healthcare services offered.

This exercise has manifestly improved students’ skills in selecting appropriate keywords from the essential and foundation questions they had developed and organizing these keywords within coherent keyword-category concept maps. These skills help students to better situate their information searching efforts and find relevant information in order to successfully solve problems. The following is an example of a keyword-category concept map submitted by students:

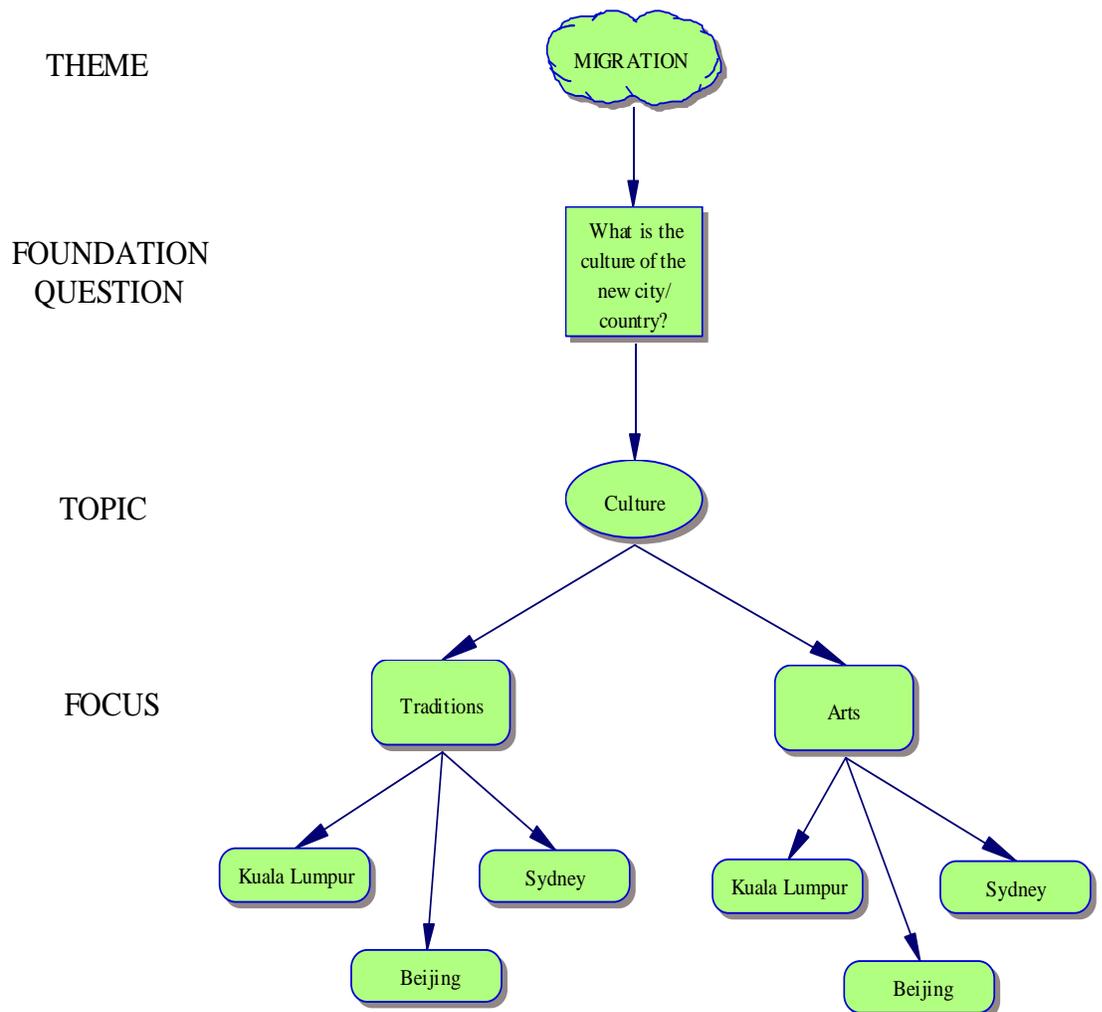


Figure 19: An example of keyword-category concept map constructed by students

In summary, this intervention framework encompassed four key phases of training aimed at improving students information searching and problem solving competencies: Learning about Internet search tools, Using information search strategies and techniques, Framing essential and foundation research questions and Developing and organizing search keywords. Internet navigation and information searching are dynamic and non-routine activities. A

reflexive model facilitating effective Internet information searching to support problem solving cannot support predictability, constancy or linearity. Hence, the phases of the framework employed in this study embodied search processes that tend to be iterative and recursive in nature, with users having to loop backwards and forwards between the phases to maintain their search trajectories and achieve targeted information goals. Instructional delivery of the training phases was carried out using a mix of teaching modes involving information dissemination and sharing, worked examples, demonstrations and facilitator guided practice tasks. An assessment of students' learning performances and achievements evidently show that students have grasped well the principles, concepts, strategies and techniques taught during the training so as to be able to function as effective information seekers and problem solvers.

CHAPTER 6: POST-INTERVENTION QUALITATIVE DATA ANALYSIS & DISCUSSION OF FINDINGS

Post-intervention phase problem 3 (Well-structured)

Problem 3 entitled 'Look before you jump' was the first well structured problem that was given to students to solve after they had undergone the first and second stages (basic tier) of the training programme aimed at improving their information searching skills.

Look before you jump.

Consider the following situation:

In the year 2005, Thailand had 34,291 cases of dengue cases recorded. In that same year, Indonesia experienced about one and a half times the number of cases. You have a smaller chance of contracting dengue in Thailand than in Indonesia.

Examine the reasoning behind this conclusion. Evaluate potential pitfalls of making conclusions with limited information. How would you respond in this situation?

This problem was classified as a well structured one since the problem solving processes, strategies and outcomes were bounded and close-ended in character with convergence in solutions highly likely. The chief terminal learning objective of this problem required students to analyze and interpret numerical data to be able to make reasonable inferences from the data. In order to solve this problem, students had to formulate effective methods of comparing figures in mathematically acceptable ways to ascertain which of the two situations is significantly more critical. Students had to employ descriptive statistics in making sense of the quantitative data and draw logical conclusions to validate their arguments based upon evidence based premises known or assumed to be true. Certain trends also possibly had to be inferred from the provided data by using extrapolation to solve the given problem.

Some of the information demands specified by students in their first meeting templates included needing to find out more on dengue fever, the causes of dengue fever and how it is contracted. Students mentioned that they had to seek more information on what is meant by having a smaller chance of contracting dengue, how this conclusion was reached and other considerations that need to be looked at besides the number of affected cases to make a valid comparison of the severity of the disease. Students also wanted to explore other attendant issues such as population and environmental differences between the two countries, extent of medical care and prevailing sanitation conditions in these countries to be able to tackle the problem.

Results

All five teams managed to correctly solve this given problem. Taking into account the populations of the countries, students did their calculations by deriving the incidence rate values using the following formulae:

$$\begin{aligned} &\text{Incidence rate} \\ &= \frac{\text{No. of cases}}{\text{Total population}} \times 100\% \end{aligned}$$

For 2005, Indonesia's incidence rate of 0.026% was found to be lower than Thailand's incidence rate of 0.053%.

Discussion

For any cogent comparisons to be drawn to solve the given problem, numerical data had to be arithmetically manipulated and expressed in terms of rates. A cursory perusal of the raw data indicated that the number of cases of Indonesia (47,633 cases) was higher than that of Thailand (34,291 cases) in 2005. It seemed that Indonesia's situation was worse than Thailand's. But students knew that a common contextual basis had to be established as the basis for numerical comparison. Commonly and not unexpectedly, the construct chosen by students for comparison was the total population of the two countries in 2005. Searching the Internet for relevant information, students rightly estimated the respective populations of Indonesia and Thailand to be respectively around 200 and 65 millions. Calculations were done by computing the percentage ratio of the recorded cases of dengue infection to the total population of the country (about 0.026% for Indonesia and 0.053% for Thailand). The computations obviously revealed that there was a higher

chance of contracting the disease in Thailand than in Indonesia. Two groups – teams three and four analytically attempted to make greater sense of the calculated figures through further mathematical manipulations and presented their final answers in terms of incidence rates per 1000 people i.e. 53 out of every 100 Thais were infected vis-à-vis 26 out of 1000 Indonesians who came down with Dengue fever. This added dimension of calculations improved clarity in students' presentation and augmented their understanding of the conceptual meanings conveyed by the numbers. Students in these two teams also argued relevantly that instead of limiting calculations to only one year of records, more research could be done to extrapolate at least 2 to 3 of the previous years' records to enable more comprehensive analysis to be done and ensure consistency in findings.

Besides using population statistics as the baseline for comparison, students also suggested examination of other associated factors in comparing the dengue situations in the two countries. This clearly showed that students had attempted to deconstruct the problem from different angles of analysis. Some of the factors that were specified included varying geographical land sizes of the two countries, inter as well as intra socio-economic differences in living standards, climates of the two countries, pro-activeness of the governments in tackling the outbreak, the availability of resources in curtailing the wider spread of the disease and the degree of manpower readiness in effectively marshalling resources. However, disappointingly, none of the teams delved deeper into these individual topics and glossed over them briefly in the presentation delivery of their solutions.

Team three succinctly summarized the learning gains from this problem solving session with the following conclusion in their presentation: “It is very difficult to come to a conclusion with limited information. Jumping to a conclusion hastily based upon lack of information would result in wrong decisions and consequences. We have to search for and collect as much information as would be possible. Then we have to analyze the information for their reliability to investigate the situation thoroughly and then take action.”

Students ascribed their successful problem solving performance to improved information search abilities gained from having attended the first installment of the intervention training programme. The learnt skills enabled students to become more competent information searchers who could leverage upon a host of information search tools and strategies in effectively performing problem solving. The high problem solving success rates was also attributed to the fact that the given problem was well structured, easily solvable and had convergent solutions.

At the end of this problem solving episode, students came to recognize that jumping prematurely to conclusions due to time constraints or a superficial reading of a problem situation without applying proper deliberation and reasoning could potentially lead to flawed analysis of the actual state of the situation. They also understood that there is no inherent value embedded within data if it is isolated from meaningful contexts and situated application. Insufficient or irrelevant research information as well as incorrect choice of contexts for comparison contribute to less than desirable comprehension of a problem situation. Taking into consideration possible time constraints,

students learnt that it is crucial to look at the context, conditions and circumstances associated with a problem scenario to be able to come to unbiased conclusions.

Students' reflection journal inputs

The following reflection journal trigger was released to students for them to post their online ruminations in relation to the given problem. Students' reflections were then collated and qualitatively content analysed for salient findings.

“How useful did you find the set of information search skills earlier taught? Did you apply what you had learnt in searching for information to solve this problem and if so, how?”

Strategies in conducting information search

Students had chunked and distributed the search load amongst the team members with each member being assigned their share of the search tasks to be executed. The individual search outputs of the members were then assembled together and organized within a coherent organizational scheme to be submitted as the collective team solution. Students explained that some of the information they actively sought for included the number of dengue afflicted cases (in order to verify the veracity of the figures mentioned in the problem statement), the total number of death occurrences due to the dengue menace, the population statistics of Thailand and Indonesia. Other sought information was on preventive measures implemented to tackle the dengue epidemic, sources of widespread dengue outbreak and background facts on dengue fever. Needless to say, the Internet was relied upon as the sole source

of information access, with one student mentioning that “I could easily and quickly find information in the Internet compared to researching through books. All I need to do is key in the search terms and immediately I am furnished with information by the Internet. I save so much of time, instead of browsing through so many books in the library.”

(student R)

Positive impact of intervention training

All students overwhelmingly agreed that the delivered information literacy training positively improved their information seeking abilities and well-structured problem solving cognition. They noted that the taught skills also had an affective impact upon them in boosting their confidence levels at being able to successfully locate and use Internet information. Being aware of the different information searching techniques enabled students to achieve better problem solving mastery. Students explained that the repertoire of skills learnt expanded their information searching capabilities and enhanced the quality of their problem solving experiences. This resulted in better learning engagement, productivity and outcomes. Overall, students strongly attributed their improved learning performance for this well-structured problem to the instructional efficacy of the interventionist training programme. They asserted that they will definitely apply these skills in the future during their information quest attempts.

Some excerpts from students' contemplations supporting these findings are attached herein for reference:

"I now know how important Internet information searching skills are in problem-based learning environments. And the skills taught to us previously helped us tremendously in solving today's problem." (student B)

"Overall, I found the skills taught very useful because it helps us to try out different ways of looking for reliable sources containing information related to the given problem." (student E)

'Before the training I did not know there were so many various search strategies such as Boolean operators. I used them today and easily found the relevant information to solve today's problem.'" (student J)

Use of inverted commas

Supporting the fact that the taught information searching skills had indeed enhanced their problem solving abilities, a significant number of 19 students expressed that they had used enclosed inverted commas at least once during the problem solving session in crafting precise search terms. This ensured that the displayed output by the search engines was more focused, specific and matched desired search objectives. Hits irrelevant to the search task were filtered out and students had an easier time locating relevant Internet resources that fulfilled their information needs. Some of the students cited anecdotal examples of how they had applied this search technique of placing the search phrase within inverted commas. Student M wrote in her reflection journal that "I used 'dengue fever' and I found it to be useful in getting the information on dengue fever I wanted. Unlike before, when I did not

make use of inverted commas and typed in *dengue fever*, a lot of unwanted stuff that provided information on dengue and fever separately was produced and I had a lot of trouble finding what I wanted.” Student C mentioned that he typed in the term “causes of dengue fever” and obtained the relevant topical information he was looking for. Wanting to comparatively evaluate the efficacy of the search strategy of entering inverted commas, he tried applying the same search term but this time without the inverted commas and was overwhelmed with pages of redundant search results.

Use of Boolean operators

Fourteen students found the search technique of being exact by applying arithmetic Boolean operators to be another powerful technique that they extensively employed in executing their information searching. The Boolean function *AND* or alternatively + was especially found to be popular in usage amongst students. It consistently yielded more pertinent search output. For example, students commonly used *population + Thailand* and *population + Indonesia* to successfully find the total population numbers of these two countries. Student Y explained that she tried inputting the search phrase of “*geographical area*” + *Indonesia* and found the necessary figures on the size of the land mass of the country whereas an earlier search attempt using the term *area of Indonesia* without quotes failed to procure intended results. Student U correctly entered the search words of “*dengue cases*” + *Thailand* + *2004* to locate reports on the statistics of the number of dengue cases for the year 2004.

Use of multiple search engines

Thirteen students highlighted that spreading their information seeking efforts over multiple search engines enhanced both the quality and reliability of accessed information. This enabled students to efficiently mine the Internet for a broader pool of relevant information materials and also cross-reference found information for its authenticity. For example, student U recorded the following corroborating observation in her reflection journal: "I also made use of different search engines which I did not know existed before the training to search for information. This helped me tremendously in finding more resources for the information I wanted. For example I used a mix of Metacrawler, Ask Jeeves, Google and Snap search engines." Student D averred that he largely relied upon meta-search engines to do his searching and found the end results to be more accurate. Separately visiting individual search engines would have been far more time consuming. Another student A realized that by using search directories her research efforts became more reliable, though limited at times - primarily due to the constrained database of available resources.

Use of search strategies

Student F mentioned that in conjunction with accessing multiple search engines, she also used attendant search strategies such as wide search and general knowledge in carrying out her search activities: "We used Yahoo! website which is a search directory developed over a long time with lots of editorial care. Its information is of high quality and is easy to use. We also used Google to find information. Though of a lesser degree of reliability, it won

the search engines watch award in 2004. Google will also offer us suggestions to correct spelling of search term when misspelt. We used some search strategies such as wide search definition and use of our prior knowledge. This provided us with a lot of sufficient resources.”

Students' misconceptions

Though students' reflections were predominantly positive in affirming the pedagogical benefits of the instructional training provided, some of their responses expressed concerns as well as reflected misconceptions. Student W, though acknowledging the usefulness of the taught skills, felt a considerable amount of discomfort in utilizing them in problem solving. This was primarily due to the lack of extended practice in applying these skills. This feedback highlighted that the learning gains from implementing the advocated training framework tend to be incremental and progressive. Students' maturation in attaining fluency in and mastery over effectual information searching skills demands significant investment in time and practice.

In the construction of appropriate search terms, two students – G and K displayed flaws in their conceptual understanding of the principles taught. Student G had repeatedly entered the search term of “*dengue cases in Thailand during the year 2005*” in order to research more on the number of dengue cases in Thailand in 2005 but failed to retrieve any useful information. The query expression enclosed within inverted commas was unnecessarily lengthy and hence undermined the effectiveness of the search inquiry. A better defined search phrase would have been “*dengue cases*” + *Thailand* + *2005* and this would have more likely produced the desired search results.

Student K had typed in the search term of “*dengue cases + Indonesia*”. This is obviously erroneous since the search engine will now constrain its search efforts to electronic resources that contain the expression *dengue cases + Indonesia* in the presented order, inclusive of the addition symbol! The correct search term should instead have been “*dengue cases*” + *Indonesia*. Student K did not know where the closing quotation mark had to be inserted to ensure that the search phrase was accurate and appropriate. Both of these students were then provided with remedial instructions to rectify their misunderstandings and improve their grasp of the fundamentals of effective information searching.

In summary, students’ positive feedback shows that they had benefited from the first phase of the mounted interventionist training program and had become more proficient in correctly utilizing the various Internet search tools and applying strategies and techniques. These set of skills were evaluated to be an important enabler in influencing problem solving outcomes and improving students’ well-structured problem solving cognition. This was amply demonstrated by students’ enhanced problem solving performance in successfully tackling the given well structured problem after having undergone the first phase of the training interventionist program.

Post-intervention phase problem 4 (Ill-structured)

Problem 4 entitled ‘What do you mean’ was an ill-structured problem that was given after participant students had completed training of the first phase of the information searching skills interventionist training programme.

What Do You Mean?

Examine the following images. What makes up a concept? What is meant by fat?



Sumo wrestlers preparing for a match in Japan.



A teenager at a fast food joint.



Russian ballerina Anastasia Volochkova was fired by Moscow's Bolshoi Theatre for being too fat. She is 168cm and 50kg.



A client from Expressions Slimming Centre: "I used to be very self-conscious; after losing my puppy fat, I am more outgoing and daring!" (picture taken at 54kg, before slimming programme)



Picture of pregnant woman



Picture of newborn baby

Being a situated ill-defined problem, the problem elements were not clearly spelt out, the goals or outcomes of the problem were not well articulated, the problem contained multiple inquiry paths and information needed to solve the problem was not explicitly stated in the problem statement. It was not possible to easily derive definitive solutions to this problem since it was difficult to conceptualise the problem and accurately determine the information or skills needed to solve the problem. The problem determinants were either vague or unknown and the contours of the problem scope not easily identifiable to be able to readily map out acceptable solutions. Student L rightly contemplated in her reflection journal that the problem poser was “more of an open-ended question with solutions encompassing our own thoughts, prior experiences and also research from the Internet.”

Typically, this is a social dilemma problem in Jonassen’s typology of problems. It encompasses a broad spectrum of topical themes tied to everyday real life issues that have to be investigated in order to understand

and analyze the given problem. The problem is grounded within a social context that is replete with personal and ethical dilemmas, giving rise to considerations that are unpredictable and at times in conflict with one another. Social dilemmas induce a state of cognitive dissonance in the minds of solvers in having to reconcile between one's individual personal self-gains and that of serving the interests of the larger society for communal good (Schroeder, 1995). The natural impulse of humans is to strive to satisfy their own personal self-interests by sacrificing ideals associated with working for the common good of society at large. Engagement with this problem cautioned students against cultivating such unhealthy dispositions and instead adopting an outlook that is more holistic, inclusive and accommodative of differing perspectives. The multi-faceted problem solving demands gave this problem its ill-structured character by requiring students to take into consideration a multitude of factors involving moral, cultural, health, physical and economic implications.

The terminal learning objectives specified for this problem solving lesson included training students to formulate inter-connecting relationships between meanings of words and their situated contexts, appreciate social concepts as value-laden meanings that are constructed through consensual negotiations and recognize the limitations of dictionary definitions. Some of the enabling learning objectives involved guiding students to understand the dilemma of 'fat' within different contexts (sports, ballet, fertility etc.) and from different perspectives (artistic, medical etc) to be able to offer a variety of definitions predicated upon different value systems (e.g. what current/earlier

society finds acceptable or fashionable, how women are perceived, what is considered cute or unhealthy etc). Students were required to explain how different stakeholders view the same phenomenon from multiple angles of reasoning, shaped by their prior subjective experiences and socio-cultural backgrounds. Students had to challenge traditionally accepted static understandings of a concept by scrutinizing related issues from broader, varied perspectives. Students also needed to realize that certain arguments tend to be broader or narrower than others and their contextual application is contingent upon their situation-specific usefulness. In seeking solutions, solutions to dilemmas are not derived based upon discrete or isolated definitions but are intrinsically shaped by a shared repertoire of experiences, attitudes and resources.

An examination of students' entries in their first meeting templates in defining the information demands associated with this problem showed that students realized a need to research further into the subject matter of fatness from different perspectives of understanding to better appreciate fatness as a concept. This they believed would enable them to open up their minds to exploring alternative outlooks, beliefs and standpoints. Students questioned the etymology of the word 'concept' and how people are predisposed to drawing meanings out of concepts. Students also wanted to investigate more on how the notion of fatness is defined as a concept and which factors influence these definitions. Students also wanted to find out more on how personal opinions impact perceptions on how a fat person is looked upon and whether someone who is fat is necessarily always ugly or displeasing.

Results

Team 1 began their presentation by defining a concept and how it is created through perceptual thinking. Students in this team next looked at the different perceptions of fats. From a positive viewpoint, fats are sources of energy that supply nutrients and protect certain vital organs by forming an insulating layer. On the other hand, fats can be disadvantageous when present in excessive amounts in the body as they result in obesity and pose health risk factors in triggering many diseases such as heart attacks and diabetes. Students viewed the sumo wrestler as not being fat since the sports equated fatness with strength. Students noted that the person taking fast food was overweight due to unhealthy diet and eating lifestyle. On the other hand, they felt that a ballerina has to be of an acceptable weight to be able to dance elegantly and expressed ambivalence about the image of the smiling lady as they did not know of her height to be able to make a call on whether her weight was reasonable. Students mentioned that the extra weight put on by pregnant women and chubby babies is nature's choice and normal too. Finally, team 1 concluded its presentation by stating that there is no definitive way of defining fatness. It is context dependent and contoured by one's value system.

Team 2 commenced its presentation by first attempting to define fats (as greasy water insoluble solid as well as semi solid chemical component found in food) before proceeding to explain the advantages of fats. Some of the benefits of fats mentioned included absorption of vitamins, promotion of body growth and insulation of nervous system tissue in the body. The first impression of students in this team when they looked at the picture of the

sumo wrestlers was that they were tough and strong though eventually students viewed the wrestlers to be overly obese. Students perceived that the lady taking junk food has an unhealthy diet causing obesity. Their analysis of the ballerina picture was that she looked reasonably good as there weren't too much of fats in her body. The team wrapped up their presentation by characterizing a concept as something thought or imagined and a broad principle that affects perceptions and behaviours.

Team 3 started off its presentation by explaining about factors such as culture, environment and society that impact human perceptions of a concept. Students in this team noted the general tendency of most people to perceive a fat person as being overweight and not good looking. They then presented the BMI values that classify a person's fatness from a scientific perspective before proceeding to explain and rationalize their consensual understanding of the meanings conveyed by the different pictures. Team 3 felt that sumo wrestlers have to be fat as they need a lot of strength and weight to pin their opponents and win matches. The students in this team also argued that ballet dancers need to be slim since their profession required them to be elegant and not too heavy to be able to dance gracefully. They were of the opinion that the picture of the smiling lady demonstrates her lack of confidence when she was fat and how her outlook improved after exercising at a well-known slimming centre. Students in this team expressed that the 'fatness' of a pregnant lady or a baby is not to be considered as obesity since this is natural and both of them need to take more nutritious food. Students also cautioned in reference to the picture of the person consuming junk food that fat teenagers taking too much

of fast food doesn't only contribute to weight related problems but also unhealthiness. In summarizing their arguments on this problem, team 3 concluded that a concept is something rich in meanings and one has to go deeper in probing and exploring a concept. In the instance of fatness, though the majority might view it as being plump, there are circumstances when being fat is desirable. So students reasoned that a person should not be judged based purely on appearance and size.

Team 4 prefaced its presentation by elucidating on what fats constitute from a scientific standpoint i.e as a category of lipids. Students in this team averred that fatness as a concept can be used in a multitude of contexts, depending upon influencing situations or conditions. To these students, sumo wrestlers represent fatness in a favourable light since sumo wrestling is highly respected in Japan and a sumo wrestler has to be heavily built to win games. Students justified that a ballerina has to be slim and attractive since being fat is disadvantageous to her career whereas the action of the lady attending a slimming programme to lose her weight can be justified since fatness in a social context is a negative perception and women are self conscious on wanting to have a perfect figure. Team 4 explained that the image of the teenager at the fast food joint conveyed the message that excessive fats can be contributed through unhealthy eating habits. The team also argued that pregnancy can hardly be associated with fatness or obesity since this stage denotes growth of another life and for some it is the most beautiful phase of a woman's life. Finally students described that fats in relation to a baby represented cuteness and subtle attractiveness to the human senses. Finally

in rounding up their presentation students spoke about the personal opinions of each of the individual members on what constituted fatness to them and how they chose to view this concept.

Team 5 began their discussions by producing the Encarta definition of concept as something that somebody has thought of, or that somebody might be able to imagine. Using this definition as the basis, students described someone who is fat to be having a big body size. Students were of the opinion that we only see one view whereas the dictionary presents different definitions of a word. In the case of the sumo wrestlers, students noted that wrestlers are required to be fat since they have to use their body mass to push the opponent out of the ring. In relation to the image of the ballerina, team 5 argued that she was not fat since from their viewpoint someone with excess flesh only can be considered to be fat. According to these students, it is the choice of the teenager at the fast food outlet to eat what she wishes to consume. They also declared that new born babies are expected to be chubby since this is genetically inherited and babies tend to eat, sleep and cry most of the time.

Discussion

Some of the learning issues embedded within this problem included analyzing definitions of concepts from different situated perspectives and constructing arguments on how concepts can be assessed for their 'rightness' or 'wrongness'. In analyzing the "truthfulness" of concepts, students learnt that it is not possible to easily categorize them as being right or wrong. Concepts do not deal with truthfulness or facts but rather they deal with how ideas are

contextually applied by social communities. Students in their initial attempts at defining the concept of fatness tended to resort to arbitrary, popular and prejudiced interpretations. For example, students were used to a negative view of fatness as a precept by defining it as excessive weight and hence undesirable - implying that someone who is fat is ugly looking and obese. This conception likely arose from being influenced by magazines and advertisements of slimming centres that equate beauty with slenderness in physique. This resulted in students having negative views of some of the images since these images were discordant with their initial views of fatness as being undesirable. Students were challenged to substantiate and defend their choices based upon rigorous logical thinking and argumentation. This prompted students to have a rethink of their earlier defective views on fatness. Students were encouraged to probe deeper on whether meanings assigned to specific concepts are fixed/factual/objective, how differentiated definitions of the same concept can be conceived and explore socially mediated possibilities of consensually understanding topical themes.

In the process of engaging in solving this problem, students became cognizant of the fact that conceptual definitions are context-specific and meanings attached to concepts differ between communities of people (e.g. fat as a concept is varyingly defined by medical personnel, artists, urban citizens, the young, the elderly etc). Training students to appreciate how different interpretive perceptions of values and meanings ascribed to a particular concept enrich one's understanding was a central focus of this problem solving session. Students realized that meanings of concepts as conveyed by

images extend beyond their physical representations into the metaphorical realm. Judgmental opinions, even if widely popular, are delimited in nature and of their own inadequate in comprehensively analyzing concepts. The notion of fat could be addressed as a descriptor for people/animals, as a class of materials, as a metaphor for excess stuff etc. The integration of these varying interpretations within an unifying framework of understanding forms the concept called fatness.

Students were encouraged to ground their inquiry on the concept of fatness from different angles of reasoning. For example, is there a significant gender bias in how girls and boys approach the subject matter of fatness? Is race or cultural background a critical factor in how views on this issue are developed? Students were reminded that concepts in themselves are not essentially right or wrong but social networks of people place a value judgment on their 'worth'. In order to try and understand the larger meaning of an idea and to holistically appreciate its usage, one needs to consider how it is interpreted and used variantly by different individuals or groups of people. This problem solving activity opened a window of opportunity in enabling students to better understand why and how different people think differently on issues of interest to them.

Overall, teams 1, 3 and 4 were able to develop and submit satisfactory solutions to the problem. Teams 2 and 5 were not too successful in their attempts at solving this problem. The teams that performed credibly well in this problem solving exercise analyzed the concept of fatness from different angles of analytical reasoning by critically examining each of the given images for

their different meanings. The teams that did not fare well failed to probe deeper into the meanings embedded within the notion of fatness and either glossed over or ignored some of the images in substantiating their viewpoints. Being ill-structured, this problem was open-ended, exploratory and non-routine. Thus, not surprisingly, students were initially perplexed and confounded when they encountered the different images embedded within the problem statement. They were unsure on how they should cognitively model the problem solving process in explaining the concept of fatness. However, the instructional guidance provided by the facilitator helped many students to better appreciate the contextual richness of the problem and understand the complexity of the problem. This problem solving activity enabled these students to broaden their mindset in learning to approach an issue from multiple perspectives and reconciling opposing viewpoints to forge integrated understandings.

After searching for information on the Internet, resourceful team 3 commendably presented a more objective and reliable indicator measurement of the construct of fatness by advocating established BMI values. The students in this group convincingly argued that such a numerical approach circumvents the problems inherent in the relative and often times biased quantifications of fatness. Within a clinical setting, fatness can be defined by calculating the BMI (body mass index). It is computed by dividing the subject's weight in kilograms by the square of his/her height in metres ($BMI = kg / m^2$). Students appropriately enumerated the following categories of values referred to in practice:

- A BMI less than 18.5 is *underweight*
- A BMI of 18.5 - 24.9 is *normal weight*
- A BMI of 25.0 - 29.9 is *overweight*
- A BMI of 30.0 - 39.9 is *obese*
- A BMI of 40.0 or higher is *severely (or morbidly) obese*

Through tackling this problem, students highlighted that they have come to realize that dictionary definitions on concepts such as fats generally tend to be limited, reductionistic and simplistic. In everyday popular social conventions, slimness is glamorized and associated with beauty whereas fatness is stigmatized and derided. However, careful analysis of the situated meanings embedded in the different images allowed students to become aware that this was not necessarily the case. For example, students from team 4 mentioned that their online information searching revealed that fatness was acceptable during the Tang dynasty of ancient China and in fact, fat ladies were seen as beautiful. One such lady frequently cited in literature is that of Yang Gui Fei.

Students agreed that the image of the sumo wrestlers evidentially supported the stance that far from being typecast as negative, fatness could actually have positive applications. Sumo wrestling is one of Japan's oldest, most traditional and highly respected form of martial arts. From a Japanese customs and traditions standpoint, sumo wrestling encourages development of huge body masses since fatness is equated with strength and valour in this sport. The grace and dignity of the pose and costume of the sumo wrestlers in the picture was noticeable. Ultimately, tactics matter more than size in winning sumo wrestling contests. However, as pointed out by team 1, bigger sizes supplied the extra edge in pinning down and outwitting opponents.

The pictures of the pregnant lady and chubby baby were other useful images highlighted as examples of situational contexts where fatness conveys positive connotations. In these scenarios, fatness is not unappealing but rather seen as the beautiful gift of nature to humanity. Pregnancy brings out the glowing radiance in women and plump babies draw the natural affection of others. Team 4 which performed well in this problem solving lesson argued credibly that the pregnant lady in the image looked jovial, contented and resplendent, stroking her bulging tummy. In this instance, the larger than normal figure denoted nobility and abundance instead of obesity as the lady was carrying another life within her. The team noted that the baby's chubbiness denoted healthiness and was appealing to the human senses.

Teams 2 and 5 encountered difficulties in explaining fatness in relation to the image of Anastasia, the Russian dancing ballerina. They could not penetrate deeper than a surface level interpretation on how they perceived fatness as projected by the picture of the ballet dancer. The members of these teams erroneously contended that Anastasia should not be considered to be overweight since fatness is considered as possession of visibly seen excessive, flabby flesh. In their estimation, she appeared to be slim with a delectable figure and wasn't fat to merit being fired from her position. They failed to read the context-specific weight demands of ballerina dancing wherein the standards of performance excellence established for professional ballet dancers are high. According to these standards, Anastasia could be judged as being overweight. Ballet is associated with feminine grace, poise and lightness. Female dancers have to maintain their balance on stage and be

light to be effortlessly carried by their male counterparts. Hence, crossing the limits of acceptable weight in this case is a disadvantage and could be characterized as something negative.

Students from teams 1, 2, 3 and 4 rightly argued that the image of the pot-bellied lady indulging in junk food as one that portrayed fatness in a negative light. The lady was obviously overweight. In this particular instance, students correctly identified that fatness had been associated with unhealthiness and obesity. The fast food culture surrounding the lady in the image was distinctly noticeable and fast foods tend to be excessively greasy or oily containing high calories.

There were disagreements amongst the groups over the representational meanings conveyed by the image of the smiling lady. The image was open to varied interpretations and the teams had different takes on the picture. This enabled students to recognize that tackling ill-structured problems is a complex yet enriching process – one that entails forging shared understandings of a broad spectrum of perspectives in relation to the problem, including those that might be opposing to their own valued viewpoints. Team 3 felt that the lady was initially fat and unconfident of herself. But after attending the weight-loss sessions in the slimming centre, she managed to shed off some weight. This consequently boosted her self-esteem and she became more gregarious. Team 1 was uncertain in their evaluation of the lady featured in the image. However, they were critical of young girls obsessed with looks falling easy prey to commercial propaganda that casts weights exceeding 50 kg to be overweight. They argued well that this sentiment was unsubstantiated

and stands in contrast to well-established health standards that define obesity not according to arbitrary weight numbers but rather in terms of height to weight ratios. On the other hand, team 4 was more empathetic and accommodating in their defense of the lady shown in the image. They asserted that there is a deeply entrenched gender bias in society towards assessing external beauty. More stringent evaluative criteria tend to be applied in determining good looks of women vis-à-vis men. Hence, the members of this team felt that the lady had done no wrong in being self-conscious of her appearance and enrolling herself in the slimming centre to cut down on her weight to achieve a svelte figure.

Students' reflection journal inputs

For their online reflection journal submissions, students were presented with the following trigger:

How useful did you find the information searching skills taught earlier and how did you apply them in searching for information to solve today's problem?

This reflection trigger enabled the researcher to gain rich insights in evaluating the pedagogical impact of the information searching skills taught in the first phase of the intervention framework upon students' ill-structured problem solving capabilities. Analysis of students' deliberations allowed for deeper understandings on the efficacy of the instructed skills on students' ill-structured problem solving cognition.

Positive impact of intervention training

Similar to the views expressed in the previous section on the well-structured problem, students registered significantly positive feedback on the usefulness of the imparted fundamental skills on effective information seeking. Students elaborated on the learning benefits gained from having attended the training session. They have become better equipped in filtering the essentials from the non-essentials in locating relevant web information. Student H aptly remarked that “.....this problem is open-ended and there are lots of supporting information to be searched for amongst hundreds and thousands of websites. So the basic techniques taught were useful in getting specific information within a short time. I applied extensively these skills today in searching for information and better understanding concepts such as fats. First, we shared some of our previous knowledge on the images and what we understood of fats. Then, with the help of the skills learnt, we conducted some internet searches and understood different views. Finally, we choose the best views that explained the images in our team’s presentation.”

Use of multiple search engines

Students learnt to use multiple search engines as search tools to scaffold their information seeking activities. Student Z, in particular, mentioned that being aware of a variety of search engines has empowered him with more choices in the selection of appropriate search engines in his information pursuits. Students realized that different search engines are designed with a varied range of features and search processing capabilities. So, a good match in fitness between the strengths of the search engines and requirements of the

search tasks to be completed has to be found to optimize search productivity. Combining the search power of multiple search engines enhanced the overall search performance. Student P pertinently stated that prior to the training she was not well acquainted with the differences between search engines, search directories and meta search engines. In fact, she was not even aware of the existence of search directories and meta search engines but is now better able to distinguish between these three dominant search tools. Another student A recounted that during her online explorations, she stumbled upon www.info.com. Based upon the knowledge acquired from the training, she recognized it to be a meta search engine and found it to be an useful tool since it was able to present the search index output from the databases of individual search engines.

However, some students noted that their integrated attempts at employing multiple search engines in support of their search efforts was not without its share of teething problems. The common obstacles encountered were difficulties in seamlessly switching between multiple search engines during information searching activities and being fully aware of the functional capabilities of the myriad of search engines. Students also sometimes became overwhelmed by the overload of information in cross-referencing information from the search engines for their veracity. Corroborating this piece of analysis is the following sample excerpt from student M's reflection submission: "There were a number of search engines I was not aware of till the training. I now know the existence of other Internet search engines besides Yahoo and Google which I thought were the only two out there.....I also tried

searching using Alta Vista and was impressed by the information provided which was rather accurate and detailed. Using a variety of search engines made our lives easier but also confusing. Sometimes, the results given were not reliable and unrelated to the matter.” Another student W wrote that he used Webcrawler – a search engine he hadn’t even heard before and was impressed by its natural language processing abilities. He had typed in the query term of “what is fat” and Webcrawler had ignored the common words “what” and “is” to present intended results listing from its database.

Use of Boolean operators

Fifteen students commented that they had widely used arithmetic Boolean operators such as ‘+’ in crafting their search phrases. For example, student R explained that previously when tasked to query information on baby fats, he would typically enter the two words “baby” and “fats” separately as search terms. This would naturally result in producing websites on baby and fats. Exercising the information search skills he had learnt during the intervention in this problem solving lesson, he typed in the more precise term of *baby + fats* to execute his search. Another student T indicated how she had applied the ‘+’ Boolean operator by citing an example of a search term she had used – *Russian + ballerina*. She was able to find necessary information on Russian ballerinas. Some examples of other search terms specified by students in the use of the ‘+’ operator were *‘tang dynasty’ + fats + women* and *‘acceptable weight’ + ballerina*. Seven students provided the feedback that they had extensively utilized quotation marks to frame their queries and achieved more productive search output. The technique of utilizing * in

formulating search terms doesn't seem to have been popular with students since only student B reported using it. He had used it in searching for expanded information related to the word *fat*.

Student D particularly mentioned that he is now cognizant of different techniques that enable him to formulate precise keywords and seek related information. He noted that he has grown in confidence in his web search abilities since in the past he used to type in entire sentences as search terms, only to become baffled by the copious numbers of displayed hits to be sifted through to sieve out the relevant ones. Student I said that with the help of the new knowledge gleaned from the training session, her researches on the Internet now have become more effective and efficient.

Similar to the findings related to the well-structured problem solving session covered in the previous chapter, content analysis of students' reflection journal inputs supported the utility of the taught information searching skills in enhancing students' ill-structured problem solving performances. There is evidently a positive correlation between these skills and ill-structured problem solving competencies. However, as evidenced by the moderate success rates in solving the problem and musings of students in their reflection journals, students found the taught basic information searching skills in themselves to be inadequate in rigour in fully tackling the complexities embedded within ill-structured problems. These fundamental skills only partially fulfilled their information requirements in being able to comprehensively locate needed information. There was a need for more instructional mediation in raising further students' information searching

proficiencies by being acquainted with more robust information searching strategies. For example, student Q commented that “I generally found applying the information search skills taught to us to be helpful in solving the problem but it wasn’t enough. The problem was difficult and we struggled. I think we need more help in developing our information skills to tackle these kinds of problems.” These concerns were appropriately addressed during the second phase of the interventionist training where the advanced tier of information search skills involving developing essential and fundamental research questions and organizing search keywords were taught to students.

Post-intervention phase problem 5 (Well-structured)

Students were given this well-structured problem titled ‘Who is it?’ and tasked to solve it after having attended both phases of the interventionist framework aimed at upgrading their information seeking skills. Having now completed the entire course of the training provided, students were adequately well-equipped with the necessary knowledge to be able to apply and evaluate the efficacy and appropriateness of what they had learnt to problem solving.

Who is it?

An incomplete set of bones was recovered from an abandoned warehouse in China. Investigators strongly suspect that the bones belong to a Chinese male.

As part of the Forensic Anthropologist team working to recreate a physical impression of the victim, you are given the femur and asked to gauge the victim’s height from it.

More information is given below.



- *Bone Stats and description*
- *Length – 55cm*
- *Thickness – 7.5cm*
- *Age – Estimated 17 to 21 years*
- *Findings – Bone knobs are grooved and show signs of wear, indicating that the owner might have been physically active. Scarring along the middle portion of the bone (not shown), strongly suggests a hairline fracture sustained in the past. Age of fracture is estimated to be within the last 8 years.*

This particular problem required students to assume the role of a forensic anthropologist working to reconstruct the physical profile of the owner of the recovered bones. Supplementary descriptions and statistics of the retrieved bones were also included in the problem statement. This problem can be characterized as well-structured and bounded in scope. In Jonassen's continuum of problem typologies, this problem could be classified as a blend between algorithmic and story based well-defined problems. The mathematical ways in which this problem can be approached and deconstructed are limited.

A constrained set of elements encompass the problem space and they have to be arithmetically manipulated in seeking prescriptive solutions. The computed solution for this problem tends to be convergent and predictable. The ambit of information searching and processing for successfully solving this problem and finding a solution is largely disciplinary-specific, confined and determinate.

The terminal learning objectives stated for this problem were enabling students to realize that relationships between two real world objects can be expressed using mathematical equations or models. Students consequently had to understand that mathematical models can be nomologically manipulated to predict unknown variables. In the process of using mathematical models, students learnt to employ these models to support or critique analytical reasoning and logical thinking. The specified enabling learning objectives included training students to select the appropriate types of data to be collected for mathematical investigations and becoming adept at explaining the conditions under which data is collected. Students also had to derive empirical relationships between constructs based upon data analysis. This led to the formulation of mathematical equations or models that serve as the referential basis in predicting the values of identified unknown parameters. Equations are symbolic representations of the structure of the elements of a mathematical problem situation. Students had to demonstrate their mastery in being able to conceptually explain the rationale behind how equations or their derivatives were created and applied. They also needed to explicate the underlying purposes and limitations of the established mathematical equations.

In defining the information that needed to be searched for and acquired in order to solve the problem, some of the issues that required further investigation as mentioned by students in their first meeting templates included the definitions/characteristics of the femur, the job specifications of a forensic anthropologist and the ways or methods that could be utilized to calculate the height, given the length of the femur bone. Students also wondered whether gender and ethnicity variations impact the nature of the symbiosis between the length of the femur bone and the height of the human being. This was a pertinent inquiry since the victim is a Chinese male and anthropology research studies on this subject matter tend to have a preponderating focus on western male subjects.

Results

All five teams were successful in generating valid solutions for the problem and accomplishing targeted learning outcomes. Teams one, two, three and five searched for and located appropriate equations establishing the association between the height of human beings and length of femur bone. These equations were verified for their validity and then applied for computing values of the unknown variable of victim's height. Since the length of the femur of the victim had been given in the problem description as 55 cm, the final acceptable answer was computed to be about 1.84 metres. Team 4 decided not to use the equations found in Internet resource websites and conducted its own experiments by collecting data on the femur lengths and height measures of their classmates to establish the equational relationship between these two constructs. Students from this team obtained the linear equation of $H = 2.0F +$

70. Applying the known value of the length of femur into this equation, team four found the correct answer of 1.80 metres.

Discussion

The supporting learning framework of this given well-structured problem required students to make use of the process of systematic mathematical reasoning to identify appropriate strategies to solve this problem. Students had to formulate equations in the form of mathematical models to represent the structure of the problem and explore solutions. Some of the initial scaffolding questions students raised during their discussions in trying to conceptualize and construct the problem space included the following:

- Who are forensic anthropologists?
- What are femurs and their physical impressions?
- What is the relationship between the femur and the height of a person?
- What data is needed to correlate these constructs and form a relationship?
- What does a forensic anthropologist do and what approaches does he/she adopt in engaging in problem-solving?

In comprehending and processing this well-structured problem task, students had to cognitively represent and visualize the problem in terms of the givens, the goal, the underlying structure of possible solutions, and the problem-solving strategies that can be exploited. During this phase of problem representation, certain features of the stated problem could be activated from memory based upon students' prior knowledge. When students identify the classification type of the problem, certain schemas linked to that particular

type could then be activated. If this happens, students then proceed directly to the implementation stage of problem solving by matching the structural components of the problem to the knowledge schemas existing in memory and trying out different solution strategies. Solvers work forth by choosing appropriate equations and reaching the problem-solving goal since they recognize the structural configurations of the well structured problem state from their previous learning experiences and apply appropriate problem solving procedures. If so, little or no search needs to be performed to acquire supporting information in performing problem solving. However, if solvers fail in schema activation during the problem representation phase due to a lack of substantive previous learning experiences, students have to exploratively search out for and acquire domain specific as well as general content knowledge information. Students then gain a deeper cognitive understanding of the conceptual issues underpinning the problem and apply related theories, rules and principles in devising solutions.

With regards to the given bone analysis problem, students were generally observed to pursue the latter route of problem solving inquiry by first engaging in extensive information searching, examining or interpreting the epistemic meanings of found information, generating and testing viable solutions. Participant students generally possessed a limited body of prior scientific content knowledge to be able to intuitively retrieve cognitive schemas registered in memory, establish the relationship between identified parameters, formulate appropriate sequence of equations and eventually reach the solution goal state. This meant that students instead had to augment

their domain-specific knowledge fluency by searching for and appropriating additional information from external educational resources in engaging in problem solving.

All five teams of students generally ascribed their strong problem solving performance to the overall effectiveness of the instructional coaching imparted during both phases of the training intervention in improving students' online information searching mastery. All five groups invariably included in their solution presentations an overview on forensic anthropology and the femur bone. Understanding what these terms meant was important in solving the problem. Through information searching, students had learnt that anthropology is the study of humankind in all its aspects, especially human culture or development. This field differs from sociology in taking a more historical and comparative approach. Of particular focus to this problem is the sub-category of forensic anthropology which students correctly defined as dealing with the examination of skeletal remains for the intended purpose of enabling law enforcement agencies to determine the identify of unverified bones and solve complex cases. Forensic anthropologists largely rely upon standard scientific procedures and techniques as tools of their trade in executing their job-related tasks. Students readily found out that the femur, also called thigh bone refers to the main bone in the human leg extending from the hip to the knee. The word 'femur' is Latin for thigh and constitutes the upper leg, that part of the leg above the knee. It is also the strongest, most voluminous and longest bone in the body, with mechanical ability to resist deformity.

Teams one, two, three and five searched for and located comprehensive information on procedural guidelines and applicable associated equations in computing the unknown height of the victim. Fundamentally, these equations model the relationship between the height of human beings and lengths of vital bones such as the femur by expressing the height as a function of bone lengths, with minor variations to take into account gender differences.

Students found that prior anthropological research studies have established the relationship between the height of a human and his/her femur bone length to be a linear one that could be expressed in the form of the following equation:

$$H = aF + b$$

where H represents the height of the human being and F the femur length in centimetres. Given the femur length, students then applied this equation to infer a satisfactorily accurate estimation of the human height. a and b are constant coefficients that have also been determined empirically. Different researchers have assigned different values to these coefficients and there appears to be no common consensus in agreement on any fixed, conclusive numbers. However, students realized that this of itself was not of compelling concern in performing computations since the advocated values in the literature do not vary markedly enough to significantly impact final arithmetic output. The specified values for a range from 2.2 to 2.4 whereas b falls in the order between 60 and 63. The standard error of estimation lies in the range of 3 to 4 cm.

Instead of blindly accepting these equations presented in the websites as definitive truth statements, commendably, students in these teams exercised deductive thinking and information evaluation by assessing the veracity of the stated equations. This they strategically attempted to do so through rudimentary experimentation in class. The following course of action plan was adopted:

Working in pairs, students identified the physical placement of the partner's femur bone which extends from the hip socket to the kneecap. Either by means of a meter ruler or measuring tape students determined the approximate length of the bone in centimetres. They then proceeded to apply the located equation to calculate the theoretical estimate of the height of the partner in centimetres. Then the metre ruler is again used to obtain the actual height of the partner in centimetres. Roles were then switched. In this way, students gathered measurements involving all five members in the team and compared the calculated results using the formulas with the actual heights of the students. Within allowable limits of tolerance, if the two sets of figures matched, then the equations were deemed to be valid and applicable in determining the victim's height. A close fit in match between the 2 sets of data was found. Team one interestingly noted that in their calculations they observed the error margins to be at most 5 cm – within statistical limits of acceptance. Hence, students drew logical conclusions in deciding that the equation could indeed be reliably applied in predicting an estimation of the height of the victim profiled in the problem poser. Applying the specified value of 55 cm for the femur length of the victim as stated in the problem description,

final answers worked out by students were approximately around the reasonable figure of 1.84 metres.

Students from team two pertinently highlighted the caveat that the room for error in this data collection and analysis methodology is potentially larger considering the small sample size of subjects involved. These students substantiated this observation by referring to the central limit theorem which informs that the degree of precision of the computed answer (or the level of certainty) is proportional to the sample size. However, one major issue that all four groups had overlooked in their analysis was whether the application of these standard procedures of computation involving equations could be generalized across all ethnic classes of human beings or would certain mediating conditions such as race etc need to be considered in adopting a more contextual approach. It was evident that students did not adequately reflect upon this limitation since they failed to respond convincingly when questioned during their presentations. Students were reminded that abstract equations obtained from Internet sources need to be discerningly scrutinized for their underlying reasoning and situated context before instantiating their use in mathematical problem solving and decision making.

Team four was rather ingenious in its collective thinking and approach to solving this problem. Students from this team preferred not to rely on the information furnished in Internet websites. Instead they decided to adopt the laborious but more rigorous path of inductive scientific inquiry by conducting their own experimental investigations to determine the equation governing the relationship between the two constructs of femur length and human height.

Students collected the femur length and height measurements of eight of their classmates and tabulated them in Excel spreadsheet. Since Excel facilitates regression analysis, students utilized this in-built statistical tool to perform their data analysis and obtained the linear equation of $H = 2.0F + 70$. To better visually represent their ideas, students included in their presentations the Excel graphical plot of the line of best fit (gradient = 2.0 and y-intercept = 70). This final expression closely approximates to those suggested in literature and used by the other four teams. Using the derived linear function, the final answer of 1.80m was attained. The loop of empirical investigations was closed with the last stage of verification whereby students counter-checked their final answer for its accuracy and reliability vis-à-vis the predicted outcome calculated using the equations found in Internet resources. The figures were found to be close enough. Overall, the students in this group displayed an impressive level of learning foresight and repertoire of mathematical processing skills. The level of trustworthiness of their experimental technique, though, could have been enhanced if they had restricted their sample subjects to male Chinese students only – something they did not do but is important in this problem case as the victim is a male Chinese.

Students' reflection journal inputs

At the end of the day's problem solving lesson, the following reflection journal was published and students instructed to electronically submit their responses. Once again, students' musings were gathered and qualitative content analysis performed to gain meaningful insights into students'

perspectives on the role of information searching in the domain of well structured problem solving.

What information did you search for? Did you apply, and if so how useful did you find the information searching skills taught during the two sessions of training provided?

Three students in their cogitations expressed their perceptual views on the character of the given problem. They explained that upon reading the problem statement, they easily identified this to be a mathematical problem requiring the application of a finite set of prescriptive rules and concepts. However, they found unpacking the problem and resolving it a more challenging task as they lacked the necessary prior content expertise in mathematical modeling and analysis. Hence, students had to do a fair amount of information searching to be acquainted with required domain specific knowledge that enabled them to execute their problem solving plans. Some of the discipline-specific topical areas on which students had conducted information research included definitions of terms found in the problem statement (e.g forensic anthropology, femur), mathematical linear structuring, data collection and processing procedures, formulas or equations linking variables described in the problem statement.

Save for one student N, the rest of the students either categorically wrote that they did not apply the 2nd set of skills involving framing of essential/foundation questions and developing keyword concept maps or failed to explicitly make any reference and comment on the utilization of these

skills. Students persuasively reasoned that they found the 1st set of information searching skills to be more relevant and applicable in organizing their information searching in solving this well-structured problem scenario. Students explained that the 1st set of skills on learning about Internet search tools and information searching strategies were better aligned towards the cognitive problem solving demands of well-structured problems. Structurally, well structured problems encompass a constrained set of identifiable schematic elements, with the boundaries of the problem space being clearly defined. Task decomposition for well structured problem solving involves an information search and analysis orientation that is typically limited, bounded and domain or disciplinary specific in scope. Hence, students found that the elementary tier of knowledge on information search skills acquired in the first phase of the training intervention was adequately rigorous enough in solving the given problem. Leveraging upon the 2nd set of advanced information search skills would unnecessarily complicate the solving of well defined problems. Student N who did attempt to use the 2nd set of skills competencies outlined that he attempted to apply what he had learnt by “extracting and compiling keywords such as *femur*, *height*, *ratio*, *calculations* from the set of questions I had asked myself.”

All students who had applied the 1st set of skills attributed the widespread usage of these skills to their usefulness in scaffolding and enhancing their information search activities. These skills helped reduce difficulties in efficiently finding needed information and streamline problem

solving operations. Excerpts of typical responses from students in this regards are as follows:

“I applied the first set of skills. If I did not apply the skills taught, I would have had difficulties in searching for the information I want and may end up with a lot of unwanted information. This might slow down the process.” (student O)

“The skills taught were definitely useful as they helped us to narrow our search and get relevant information. I avoided unwanted and unnecessary information and this helped me to find the resources in no time and increase my efficiency in searching for information.” (student D)

Use of Boolean operators

Next, students detailed some of the ways in which they had incorporated the 1st set of skills in their information seeking and found them to be of utility. Commonly, students cited the use of the arithmetic operator ‘+’ and the quotation marks in framing their search terms. Capitalizing upon these search techniques enabled their searches to be more precise, reliable and effective in cutting through the online information maze and locating desired information. For example, student L noted that “I put in *femur to height ratio* as search term but couldn’t find the information I wanted. I used the other method which is putting in the plus sign. I put in *femur + height +calculations* as my search key and indeed there is so much of information on the relationship between our height and femur bone.” Another student E mentioned that “I made use of the words *‘forensic anthropologist’* as the search topic, which made searching for information on forensic anthropologist much easier instead of separately *forensic* and *anthropologist*.”

Use of multiple search engines

Fifteen students reflected upon the integrated usefulness of multiple search or meta-search engines in optimizing their information search outcomes. They averred that such a strategy allowed them to access a wider database of website indexes and cross reference search results for better fidelity of abstracted information. Hence, the varying strengths of different search engines were well exploited. Corroborating this finding on the usefulness of performing information searching across different search engines, student S articulated the following in her journal entry: “Yahoo, although having larger search results and being popular amongst all, also has a lesser degree of reliability. Due to the huge range of search results, it will take me quite some time to find the information or sometimes not at all. Using Alta Vista allows the search for results lists in standard, compact, detailed form. There is choice between simple and advanced searches and I get more accurate information.” Student V shared his observations on how accessing a multiplicity of search engines improved his searches in covering a wider spread of information output. However, he rightly also added a note of caution that pooling information from different search engines is a time consuming endeavour and meta- search engines are not necessarily more productive than individual search engines in procuring related information.

In conclusion, analysis of the data from students’ descriptive responses in their reflection journals establish the positive influencing effects of the first set of information search skills on well-structured problem solving performance

and outcomes. There is evidently a strong correlation between these mediating skills and successfully resolving well-structured problems. Applying these skills in solving well-structured problems improves problem solving performance. On the other hand, there is a weak or non-existent impact of the 2nd cluster of information search skills on the productivity of well structured problem solving processes. The 2nd set of skills, being more advanced and sophisticated, unnecessarily adds complexities to the stepwise procedures involved in solving well-structured problems. These skills impose a cognitive overload of extraneous information planning and processing work on students, thus preventing them from promptly seeking needed information and obtaining required solutions.

Post-intervention phase problem 6 (Ill-structured)

The sixth and final problem that was used as the performance indicator in evaluating the efficacy of the composite effects of the Internet information searching skills training intervention program on students' ill-structured problem solving cognition was given to students after both phases of the training program had been completed. The problem entitled 'Candle in the wind' was

Candle in the Wind

Analyse a candle and the various representative meanings associated with the candle to construct better understandings of the significance of a candle (with an attachment of a picture of a candle).

This was primarily an ill-structured problem since it was designed to yield larger individual variability in problem solving strategies and solution outputs. What gives this problem its ill-structuredness are the multiple solution pathway options solvers face in identifying the essence of the problem, devising goals, formulating possible solutions and choosing the best solution. Being less definable and more open-ended, solvers have to combine or recombine networks of cognitive schemas in response to the requirements of the problem, rather than merely retrieve and apply a single existing schema from memory. This problem requires engaging a varied range of analytical problem solving processes in constructing the problem space and generating possible solutions. There is no one constrained set of rules, principles and concepts that could be applied in cognitively modeling and solving this problem - divergent or alternative solutions are possible. There are multiple criteria in evaluation of solutions and reaching a consensual agreement on an acceptable solution is not an easy task. The solving process becomes complexified as students have to develop arguments by gathering evidences, expert opinions, and synthesizing a gamut of perspectives to support their standpoints.

The terminal learning objectives for this lesson included enabling students to appreciate that we could use various aspects of analysis to make sense of situations. Students came to not only appreciate but apply the different components of analysis such as deconstructing a complicated situation into individual elements or themes, understanding the meaning and

relationship between these individual elements and then constructing integrated meanings to make sense of the situation. Finally, students had to recognize that the analysis done in a particular situation or context could vary within this general framework, depending upon the objectives to be met. The purpose of analysis is to make inferences, i.e. to make explicit (stated) in one's analysis what is implicit (unstated but suggested) in the object of analysis.

The enabling learning objectives that had to be met for this particular problem solving session included training students to examine the candle from various facets or angles of inquiry and apply judiciously the relevant frameworks of analysis to better understand the individual facets.

For example, a chemical analysis of the candle would involve understanding the various components that would make up a chemical analysis. Students had to recognize how the individual components from a facet of analysis relate to and mutually inform other facets in building up layers of meanings. Students then had to holistically integrate the meanings of the different components within a unifying framework to forge a better understanding of the representations of a candle. Finally, students had to recognize that different forms of analysis employ different frameworks of research.

In analyzing the information needs of this problem for it to be solved, students specified in their first meeting templates that this problem demands a repertoire of analytical skills to be used to investigate how the symbolism of the candle could be thematically dissected into different aspects and what the outcome-based goals of undertaking analysis are. Students also wanted to

find out more on the set of evaluation criteria items that had to be referenced to in examining the candle and its meaning representations.

Results

The following concept maps encapsulate the organizational structures of the key ideas of the different teams in organizing their solutions to the given problem:

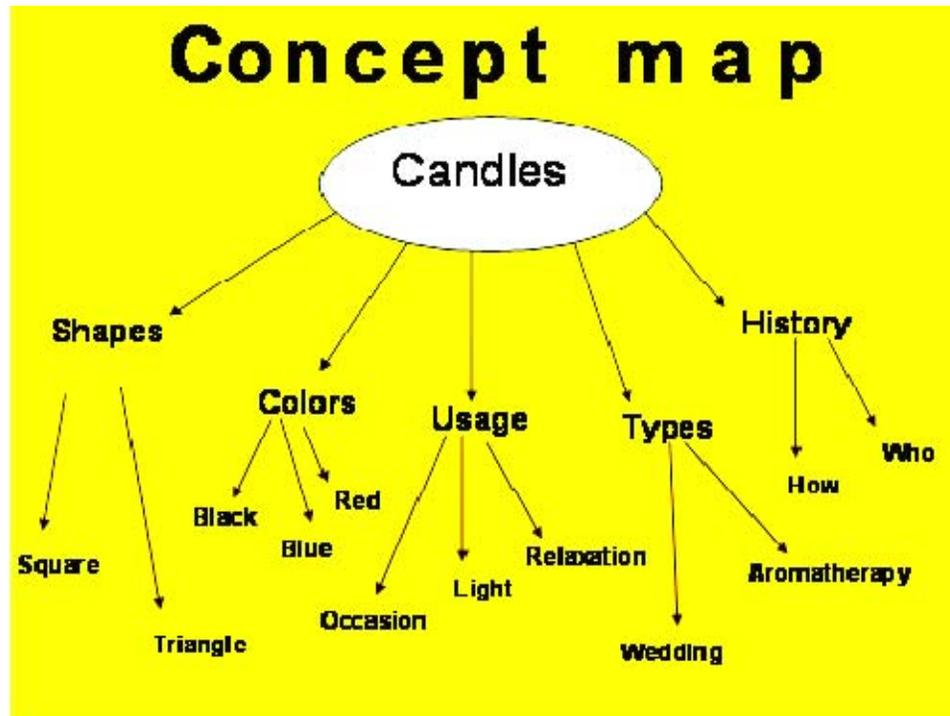


Figure 20: Team 1's concept map

Analysis of candles

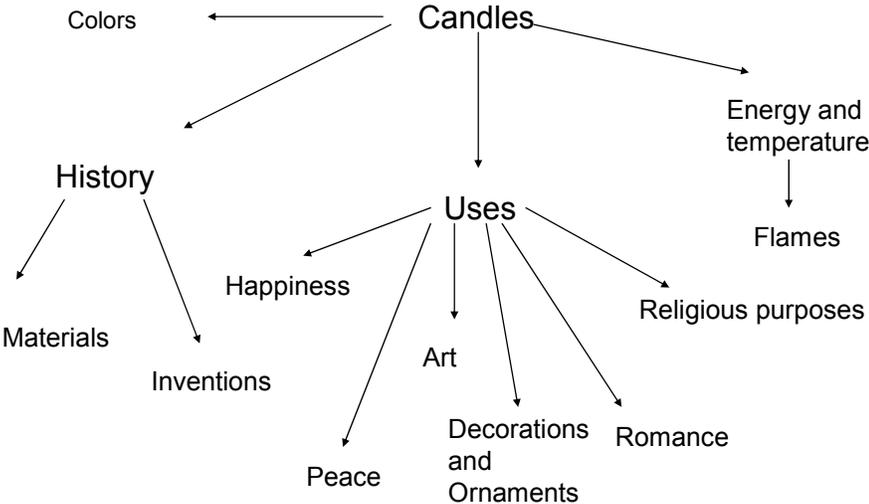


Figure 21: Team 2's concept map

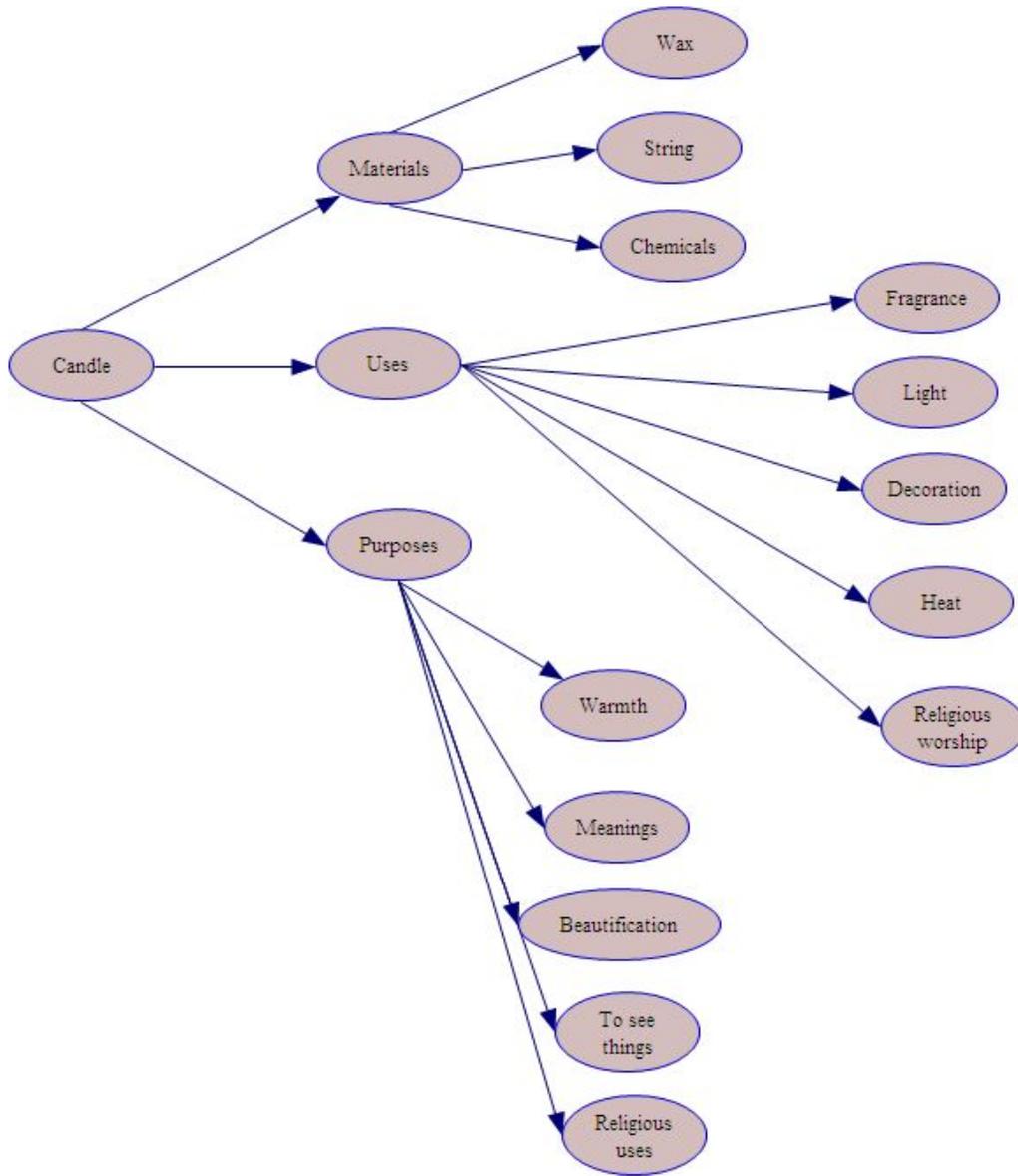


Figure 22: Team 3's concept map

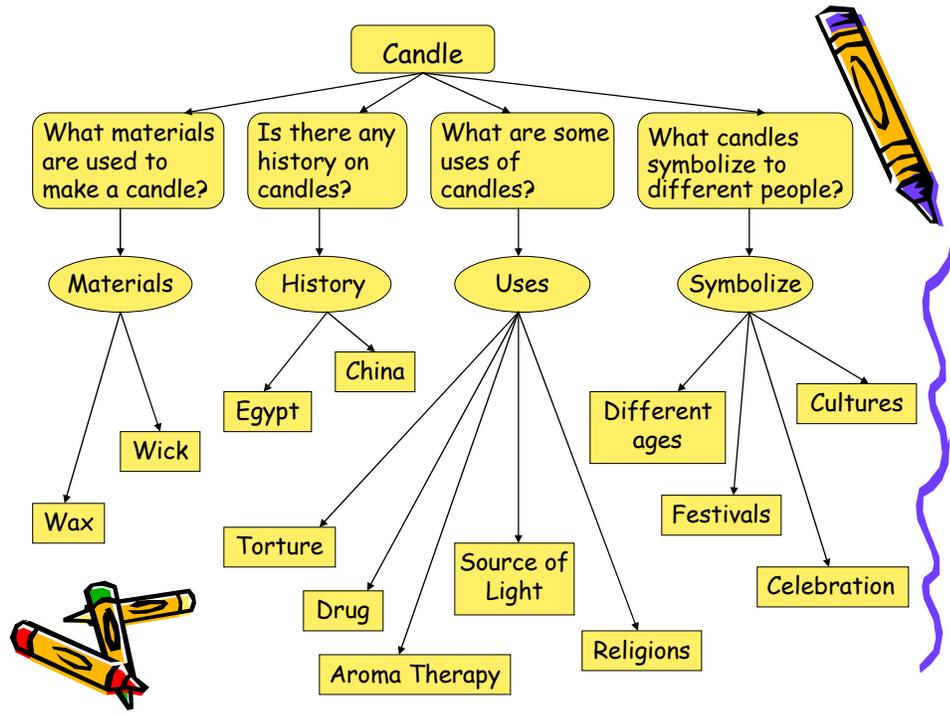


Figure 23: Team 4's concept map

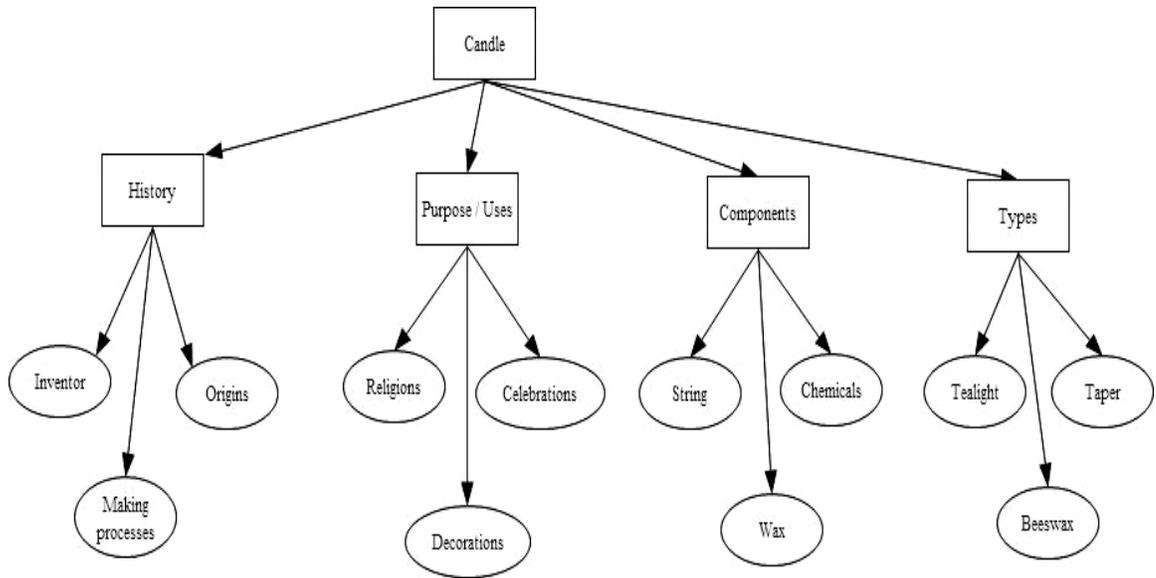


Figure 24: Team 5's concept map

Discussion

Some of the investigative learning issues embedded within this problem solving included scrutinizing what a candle does, the ingredient materials that make up a candle, the purposes for which a candle is used and the spectrum of meanings associated with a candle. Students also needed to query how an object or concept can be analysed and the processes involved in such an analysis. Students had to reflect on how the candle could be examined for the different component meanings it conveys and what steps needed to be taken in interpretively making sense of the different facets of the candle. Students learnt that the individual components and facets when integrated together afford deeper understandings of the candle, inclusive of its literal, metaphoric and emblematic representations.

All five teams in the class performed credibly well in this ill-structured problem solving task and were able to successfully solve the problem and fulfill the learning goals of the lesson. These five teams had also extensively applied the principles of effective information searching skills taught during both phases of the intervention training in their information research pursuits in seeking solutions to the given problem. This was expressly evident from the group presentations and the analysis of artifacts submitted by these students – all five teams had developed a protocol of guiding essential and foundation questions and structured their information seeking activities by constructing keyword concept category maps. These concept maps served as strategic scaffolding aids in enabling students to efficiently implement their search plans and process relevant content information. The good quality of students'

products, particularly the structures of the concept maps and students' learning performances for the day manifestly demonstrate the positive impact of the imparted training in improving students' information literacy and problem solving mastery levels. All five teams listed the question of "*What is a candle and what does it mean to different people?*" or closely-related variants as the key essential questions that framed their information research for this problem.

The first group of students researched the Internet for information on this problem and decided to systematically organize the information they had gathered within a 2-tiered taxonomy comprising of 5 broad classifications. This was a well-planned and coherent schema of knowledge codification consisting of a reasonable number of thematic categories. Students were thus able to explain and defend their solution in a structured and convincing manner. Students specified the following key foundation questions: "*How did candles originate?*", "*What are the different types of candles?*", "*What are the different colours of a candle and their individual significances?*", "*What are purposes or usages of candles?*" and "*What are the various shapes of candles and the meanings conveyed by them?*". Team 1 devised a concept map consisting of the 5 keyword groupings of shapes, colours, usage, types and history in framing their solution to this problem on analyzing the candle and the different meanings it suggests.

Students from team 2 modeled a problem solving approach and solution plan quite similar to the first group's but replaced the category of shapes with one on energy and temperature. This thematic category was derived from the foundation question of '*What is the energy and temperature*

of the flame?". However, surprisingly, no information on this category was furnished during the team presentation and content material on this category was again missing in the submitted solution product. This omission was highlighted to students and it was also pointed out that this category on energy and temperature seems neither cogent nor persuasive enough in terms of substantive content relevance.

Team 3 decided upon a solution schema that comprised three crucial broad-based categories: uses, purposes and materials. The content in the first two classes of categorization on uses and purposes was not distinguishably distinct from what the first two teams had presented, though the terminologies used in labeling the categories were different. Unlike the first two teams, this group of students had overlooked the vital topic of the colours and shapes of different types of candles. In addition, the ways in which these students had organized and presented their solution information output were not particularly well-sequenced. However, what gave them the added edge over the first two teams was their inclusion and detailed explication of the category on materials. Originating out of the root foundation question of "*What are the composite materials that make up a candle and their significance?*", other sub-topical questions such as "*What are the chemicals in the candle?*", "*What is the role of wax and strings in the burning of a candle?*" were generated by the students. Though, there was room for improvement in the information presentation, layout and structure of the solution submitted by this group of students, it was noteworthy that the information research that had been done was extensive and comprehensive.

The classification groupings developed by teams 4 and 5 in brainstorming, structuring and arranging their key ideas were, in essence, similar to the previous three groups. The variations noted in their concept maps were minor and not very significant. The first three categories that both teams had formulated were similar to what the previous three groups of students had thought of in their analysis of the candle and its meaningful representations – materials/components, history and uses/purposes. The only difference was in the fourth category – team 5 defined its interpretation of candles in terms of the variegated types of candles whereas team 4 chose to examine the candle from the perspective of symbolism. Students from team 5 elucidated on the category of typology of candles in a distinctive manner since their focus was on the varieties of candles, such as tealight candle, taper candle, beeswax candle etc instead of the prevalent focus of colours and shapes of the other teams. Team 4 explored the symbolism of candles from multiple angles of inquiry involving different age representations, festivals, celebrations and cultural images. The foundation question that students had constructed that led to the creation of this category on symbols was “*What do candles symbolize to different people?*”

All five teams of students specified the elemental issue of the origins of the candle as one relevant focal area of scrutiny. Related foundation questions such as the following were raised: “*What is the manufacturing process behind the making of candles and who first invented the candle?*”, “*How did the candle first come into existence and what were underlying causes?*”, “*What is the recorded historical documentation on the candle?*”, “*What are the basic*

molecular units and chemical elements that make up the candle structure?"

Team 3 investigated the physical and chemical properties of a candle, particularly those associated with the wax, whereas team 4 researched on the necessity of the candle wick and how it impacts the burning of the candle. Students from teams 1 and 2 were inquisitive to explore more on the wide array of colours/shapes that candles come in and the matrix of meanings associated with these colour/shape representations. Team 5 resourcefully wondered on the importance of candles and their applications in modern-day contexts where spaces are illuminated by either electricity or power generated lightings. Candles, in comparison, seem rather antiquated.

For the category on materials used to make candles, students delineated that modern normal candles are usually made from wax, chemicals and string/wick. Besides wax and wicks, fragrance oil and colour dyes are other essential constituent ingredients of aroma coloured candles. Students mentioned that whilst modern candle-making processes vary, most candles are made through the timeless process of placing a cotton wick into wax which is then molded, dipped, extruded, pressed, rolled, drawn or filled into a desired shape and size.

On the aspect of colours of candles, students who had researched on this subject matter explicated that the various colours represented layers of interpretive meanings. Generally it is widely accepted that white means purity, innocence, healing and sincerity, red represents strength, health, courage and passion whereas blue conveys a sense of deep emotion, harmony, joy, peace and truth. Green colour symbolizes fertility, growth and balance, yellow

expresses confidence, devotion, cheerfulness and charm whilst brown signifies endurance, neutrality and concentration. Pink colour communicates traits of morality, honour, romance and femininity, with black connoting specters of death, sorrow and fatal endings. Interestingly, based upon their individualized perspectives, students from team 1 articulated the meanings they personally attached to candles. Candles denoted peace to student D while student X associated candles with hope. For student N, candles embodied romantic notions and candles exemplified an outlook of unbridled joy to student R.

Team 5 which analysed the different types of candles enumerated them as aromatherapy candles, beeswax candles, floating candles, jar candles, novelty candles, pillar candles, tape candles, tealight candles, wedding candles, scented candles and unity candles. This large spread of candle types affirms the wide use of candles for different purposes. For example, floating candles are of utility as decorative accessories, cultural items (in Chinese Lantern festivals) and relaxation aids. Aromatherapy candles enhance “mood setting”, therapeutically soothe the nerves as well as alleviate undue stress and anxiety. Scented candles permeate the environment with lasting fragrances, physiologically promote healthier breathing and create an ambience of ebullience. Unity candles are large ones used in wedding ceremonies and are elaborately designed to reflect the uniqueness of the wedding context by symbolizing the blissful union of two special people.

All five teams explained substantially on the different uses and purposes of candles. This broad category was generally broken up by students into several sub-components and dealt with individually in-depth. From the context of religious usages, students spoke about the universal centrality of candles in the methodologies of worship and ritualistic performances of diverse popular religions. Christians use candles as symbols in representing the light of God and invoking the grace of Christ. Candles were used to light up Christmas trees before the advent of electrical lights. In Christian traditions, advent candles which are different coloured candles are lit every evening throughout the month of December. For the Jewish people, lighting the eight candles of the menorah marks a significant commemoration of the resistance of the Jews against the Greeks and the re-dedication of the Temple in Jerusalem. In Judaism, candles are also used in remembering a departed, loved soul. For Hindus, candles play a vital role in their religious practices since candles represent the concept of Brahman or the aura of all-pervading cosmic divinity. During Diwali festivals, Hindus light up candles and oil lamps at homes to denote the victory of goodness over evil. In Buddhism, candles are widely used during the Ubon Ratchathani Candle Festival where candles are paraded through the city centre on floats accompanied by representatives of the respective institutions. In Humanism, candles have become a symbol of the light of reason or rationality and in Wicca, candles signify the presence of the Gods and Goddesses.

Other practical applications of candles cited by students included candles as stylized works of arts, romantic emblems, spiritual items, fear conquering aids, ornamental artifacts and stress/health management enablers. Team 4 mentioned that for certain ethnic communities of people, candles are integral paraphernalia of their cultural/belief systems in seeking blessings of auspiciousness and prosperity. Team 5 dealt in depth on the functional character of candles as decorative pieces. The arrangement of candles impacts styles of decoration and has been effectively used to add a more sophisticated appeal to the environment. Some place candles around the fireplace to create a fascinating backdrop that enhances the aesthetic attractiveness of the home.

Students' reflection journal inputs

The following reflection journal trigger was posed to elicit students' responses and better understand the strategies and processes they employed in researching the Internet for related information and resolving the given ill-structured problem theme:

If you did use, how did you apply the taught Internet information searching skills (both sets of foundation and advanced skills that have been taught) in solving today's problem? How useful did you find these skills in engaging in problem solving?

Positive influence of training intervention

Twenty-two students assessed both sets of Internet information gathering skills to be relevant and beneficial in effectively deconstructing and solving the problem. They averred that efficacious information searching skills

are an important function of successful problem solving. The few students who did highlight difficulties encountered in the application of these skills (especially the second set on developing essential and foundation questions and creating keyword categories mind-maps) noted that they arose primarily out of students' unfamiliarity and lack of exposure in exercising these skills to accomplish problem solving. These students were of the opinion that given more opportunities for varied, distributed practice in honing these skills, they would become more competent in the utilization of the skills. For example student Y ruminated thus: "I am still used to my old ways of searching for information because it is not easy to change old habits and I have been using them since young. But after going through the training, I find the new skills learnt to be effective and helpful in finding information. But I will try my best to use the skills more in the future as they help me to find information more precisely."

Some sample favourable comments drawn from the data corpus demonstrating the positive impact of the instructed skills in enhancing ill-structured problem solving performance are attached herein for reference: "I can easily say that these skills are essential to problem solving. I believe the skills helped us to easily complete the task and improve my competency in searching for information in the Internet. Coming up with the mind map enabled me to brainstorm for ideas before doing any research." (student F) "All the skills I have learnt have been very useful. I will be using these skills in my daily information searching activities. This is an important knowledge I have gained." (student H)

“Overall, these skills are vital. I am expecting to use them more in future to enable me to solve problems better and in my personal life as well. As information is necessary and we need to find it to solve problems, these skills will come in handy.” (student J)

Use of techniques of question crafting

All the students in the five groups indicated in their reflection journal entries that they had widely leveraged upon the techniques of essential and foundation questions crafting and keyword concept mapping - competencies they had learnt during the 2nd phase of the intervention training. They found these skills to be particularly valuable and effectual in addressing the epistemological requirements of the given ill-structured problem task. These strategies were assessed to be powerful cognitive aids in scaffolding their self-directed learning activities. Formulating a slew of essential and foundation questions enabled the development of keenly inquiring mindsets amongst students. These questions served as the pivotal pedagogical anchors that promoted active learning. Critical questioning deepened students' understanding of subject content matter in autonomous ways and encouraged them to engage in dialectical meaning making. Consequently, applying the skills on keyword category concept mapping facilitated the methodical seeking of explanatory answers to the stated hypothetical questions. Concept maps are compelling visual tools that readily allow the organization of an array of conceptual topics and relational links between them. Student S succinctly summarized thus the learning gains from applying these questioning and concept mapping strategies to solving ill-structured problems:

“Today before doing Internet information searching, we did the concept mind map. The mind map was organized according to the essential, foundation and sub-foundation questions we had asked ourselves. We derived the foundation questions from essential questions and the sub questions from the foundation questions. After that we chose the key words from the questions and created the mind map. Then we proceeded to Internet searching.”

An unquestioning mind is increasingly reliant upon being passively fed by the ideas, opinions and solutions of others. On the other hand, independent questioning stimulates higher order reasoning. Exploring answers to questions through concept mapping allows for more focused processing of information in modeling innovative problem solving solutions. Supporting this piece of finding, student Q posited that “asking questions is easier for us to focus on searching for information from the Internet. It helped us in making decisions. To our amazement, we could easily find information and understand the problem deeper. We came up with essential followed by foundation questions. After this, our task became easier since the keywords we needed came from arranging the topic and focus inputs for each foundation question in concept maps.” Questioning and concept mapping strategies also have the added advantage of enabling students to break down the wider configurations of the problem space into manageable sub-parts, each of which is separately investigated and then information integrated within an unifying solution framework. The following piece of excerpt from student E’s postings buttresses this analysis finding: “I divide the problem into essential and foundation questions to deal with smaller parts and go deeper to find out more

on the problem. I am able to easily identify key search words and points and present them in concept maps to execute my searches. I have gained good Internet research, analytical and critiquing skills. I am able to use these skills to derive the answers as I structure my research, make better decisions and plan productive courses of actions”.

Use of Boolean operators

Twenty-three students also provided strong feedback in their reflection journal entries on the positive impact of the first set of basic skills (learning about Internet search tools and fundamental search techniques) on successfully solving ill-structured problems. 19 students highlighted the use of Boolean operators such as + and quotation marks in devising their search terms upon identification of related keywords. This ensured that their search efforts were more focused and streamlined as the search engines presented a more narrowed down and relevant listing of search results. Some sample comments of students affirming these conclusions are as follows:

“If we wanted to get information on the materials or history of candles, then we search for *candle + history* or *candle + materials*.” (student L)

“The techniques such as using ‘+’ and “ ” which I had learnt previously I applied today. I found information on candle as source of light by typing *candle + source + light* and the history of the candle by keying in the search term “*history of the candle*”. This was helpful in allowing me to obtain the information I needed.”

(student T)

“I applied Boolean (+) and (-) techniques and used “ ” in my searches frequently as it helps me save a lot of time and find relevant information. It works very well for me.” (student V)

Use of multiple search tools

Sixteen students also mentioned the use of multiple search tools in exploring and acquiring Internet information in resolving the problem scenario. Not only did this provide students with a wider coverage of information resources – something critical in attending to ill-structured problems but also allowed for cross-referencing in verification of the credibility of the found information. For example student O noted that “I know I can directly go to a website or use a search tool to look for information. But unfortunately, I do not know that many websites. That’s why I needed to use a combination of search engines, search directories or meta-search engines. I prefer different search engines since it is convenient for wide and complex searches. We also sometimes go to Wikipedia and information quickly comes up.”

Another student B similarly reflected that “I had to move on and try another search engine, especially when I was unsuccessful in finding what I wanted. Moreover, I nowadays don’t use Yahoo only as I used to. I have started to use Webcrawler as it is easy and better. I utilize different search engines to accomplish our goals and this has increased my confidence level due to less frustration in information searching.”

Impact of information searching skills on problem solving

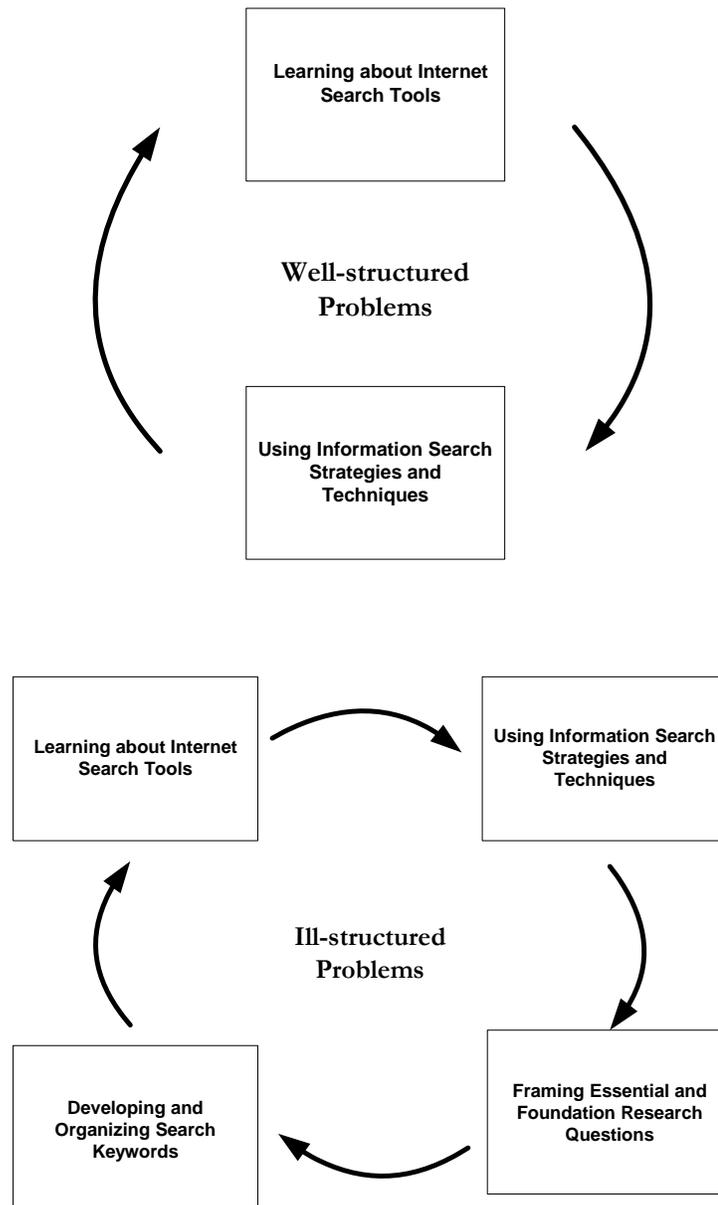
In summary, a close analysis of students' solution presentations, artifacts and reflection journal responses for the six problem-based learning lessons (three well and three ill structured problems) reveal the nature of the relationships between different Internet information searching skills/strategies and the structuredness of problem tasks. Well-structured problems require the application of a limited and known set of concepts, rules and principles within a bounded domain. Normally, the content expertise needed to solve a well-structured problem is restricted in its focus on a singular disciplinary field of knowledge. The problem space is well defined and goals as well as solutions easily identifiable or knowable. A constrained set of logical operators or sequential procedures need to be applied to decode a well-structured problem. Furthermore, well structured problems explicitly present all schematic elements of the problem to the learners. The information demands to be met and the information research to be performed in order to successfully solve a well-structured problem are delimited in scope and readily manageable. The data analysis of this study evidently demonstrate that the basic tier of information searching skills involving knowing about the working mechanisms of various Internet search tools and elementary information searching strategies are adequate enough for students to be able to competently solve well structured problems. Through instructional training, students were equipped with these skills during the first phase of the interventionist training program and found these foundational search techniques to be sufficiently

rigorous when applied in successfully resolving well-structured problem contexts.

On the other hand, ill-structured problems are encountered in everyday and professional practice. There are no clear demarcations when it comes to defining the boundary contours of the problem space of these problems. These problems do not necessarily conform to specific content disciplinary domains and the problem solving processes cannot easily be conceptualized. Ill-structured problems contain solutions that are neither predictable nor convergent. Both, elements of ill-structured problems and criteria for evaluating the efficacy of proposed solutions may not necessarily be known. These problems possess multiple or alternative solutions, goal states and pathways to deconstructing problems. The information requirements for solving ill-structured problems are complex, diverse, ill-defined and extensive. The information searching that needs to be accomplished in approaching ill-structured problems is dynamic, expansive and rigorous. The research findings of this study inform that the taught basic set of information searching skills on Internet search tools and information search strategies is of utility, though inadequate, in supporting students' attempts at untangling ill-structured problems. Proficiency in these elementary skills coupled with the instructed advanced information searching abilities involving developing essential and foundation questions and constructing keyword category concepts maps is critical to the solving of ill-structured problems. Leveraging upon the combination of basic and advanced levels of information seeking competencies helps to methodically structure and scaffold the otherwise

widely diffused and distributed information searching process involved in tackling ill-structured problems.

The following frameworks schematically outline the character of the ecological relationships between the typology of information searching skills/strategies and structuredness of problem-solving tasks:



Figures 25 and 26: Schematic representation of impact of information search skills on problem-solving

CHAPTER 7: POST-INTERVENTION QUANTITATIVE DATA ANALYSIS & DISCUSSION OF FINDINGS

In this chapter the quantitative research findings from analysis of data collected is presented. Data in the form of Camtesia recorded students' online navigational movements in the Internet when searching for information to solve problems for phases 8 and 9 respectively involving problems 5 and 6 was collected for quantitative analysis. This data was collected only for phases 8 and 9 to ensure that the maturation of the treatment effects of the taught information searching skills during intervention phases of 4 and 7 was fully attained before data analysis was carried out. Paired sample t-tests were used to test the validity of stated research hypotheses 1 and 2.

Findings for research hypotheses (1 and 2)

Power

Power is the probability that a statistic will correctly reject the null hypothesis when it is false and needs to be rejected. Power analysis is one procedure that social science researchers are finding to be valuable as significance testing in evaluating experimental effects. Power is influenced primarily by factors such as effect size and sample size. The effect size estimation reflects the strength of the relationship between the independent and dependent variables. Measures of effect size demonstrate how large the

effect of an independent variable was. A large effect size increases the power of the study. Similarly, larger the sample size, higher is the power of the study (Burns, 2000).

For the behavioural sciences, Cohen's (1988) conventions for the effect sizes are 0.2 for small effect sizes, 0.5 for medium effect sizes and 0.8 for large effect sizes irrespective of the signs. For a large effect size of 0.80 to be realized in a two-tailed study at the 0.05 significance level Cohen (1988) advocates that a minimum of 15 participants are needed for 80% power for the study. In the case of this study, a minimum power of 80% for a two-tailed test was easily achieved since 25 student participants were involved in the study.

Hypothesis (1):

There is a significant difference between the path compactness metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.

Analysis:

A paired samples *t* test (N=25) was conducted to find out whether the path compactness metric values of the navigational network structures resultant from an analysis of the information searching pathways undertaken by students differed in relation to solving well and ill structured problems. There was a significant difference between the mean values of the path compactness metric values of the information searching network structures generated in solving well and ill structured problems ($t = 4.16$, $df = 24$, $p < 0.05$). The path compactness metric mean value of the information

searching networks for solving ill-structured problems was significantly higher than that for the well-structured problems.

Hypothesis (2):

There is a significant difference between the path stratum metric values of the information seeking navigational network-based structures in solving well and ill-structured problems.

Analysis:

A paired samples *t* test (N=25) was conducted to find out whether the path stratum metric values of the navigational network structures resultant from an analysis of the information searching pathways undertaken by students differed in relation to solving well and ill structured problems. There was a significant difference between the mean values of the path stratum metric values of the information searching network structures generated in solving well and ill structured problems ($t = 3.92$, $df = 24$, $p < 0.05$). The path stratum metric mean value of the information searching networks for solving well-structured problems was significantly higher than that for the ill-structured problems.

Sample network diagrams representing the navigation structures generated in solving well-structured and ill-structured problems are respectively shown in Figures 27 and 28. These path diagrams were produced by analyzing the Camtesia recordings and plotting students' online navigational movements in seeking information to solve given problems. Each numbered node represents a unique website visited by students.

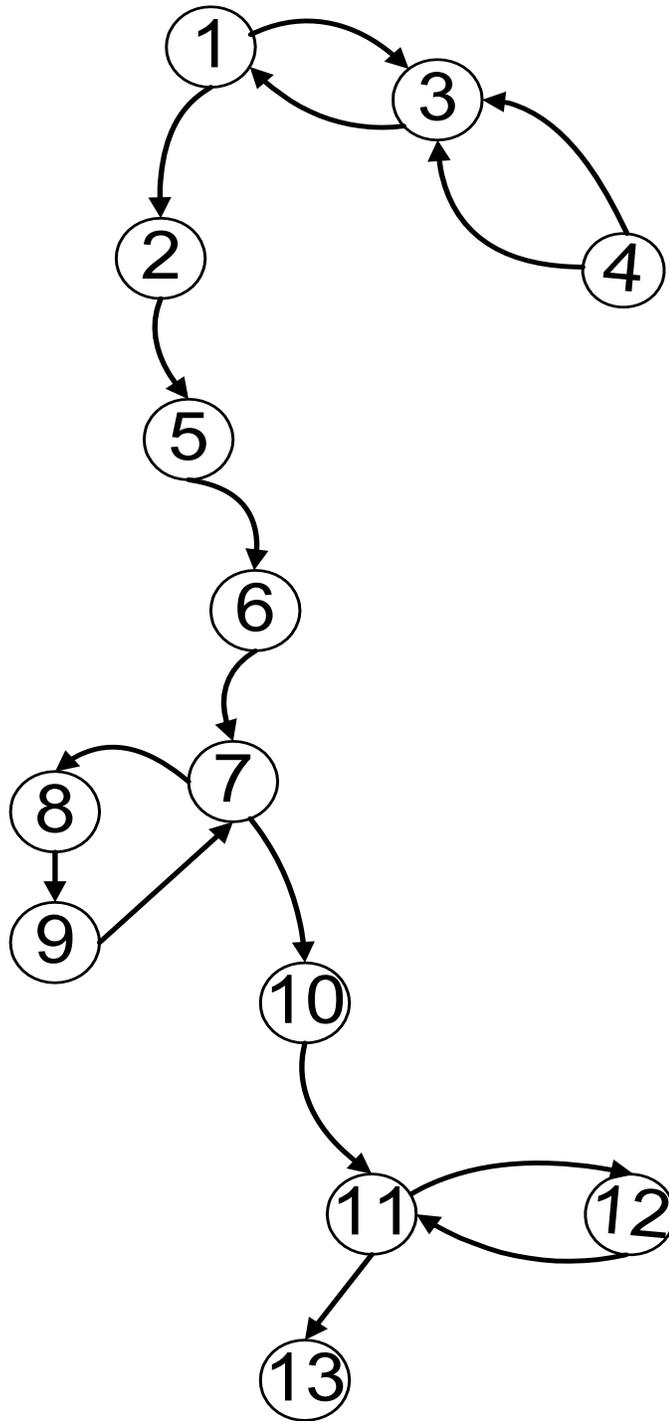


Figure 27: Network with high stratum and low compactness values that represents the information navigation structure generated in solving well-structured problems

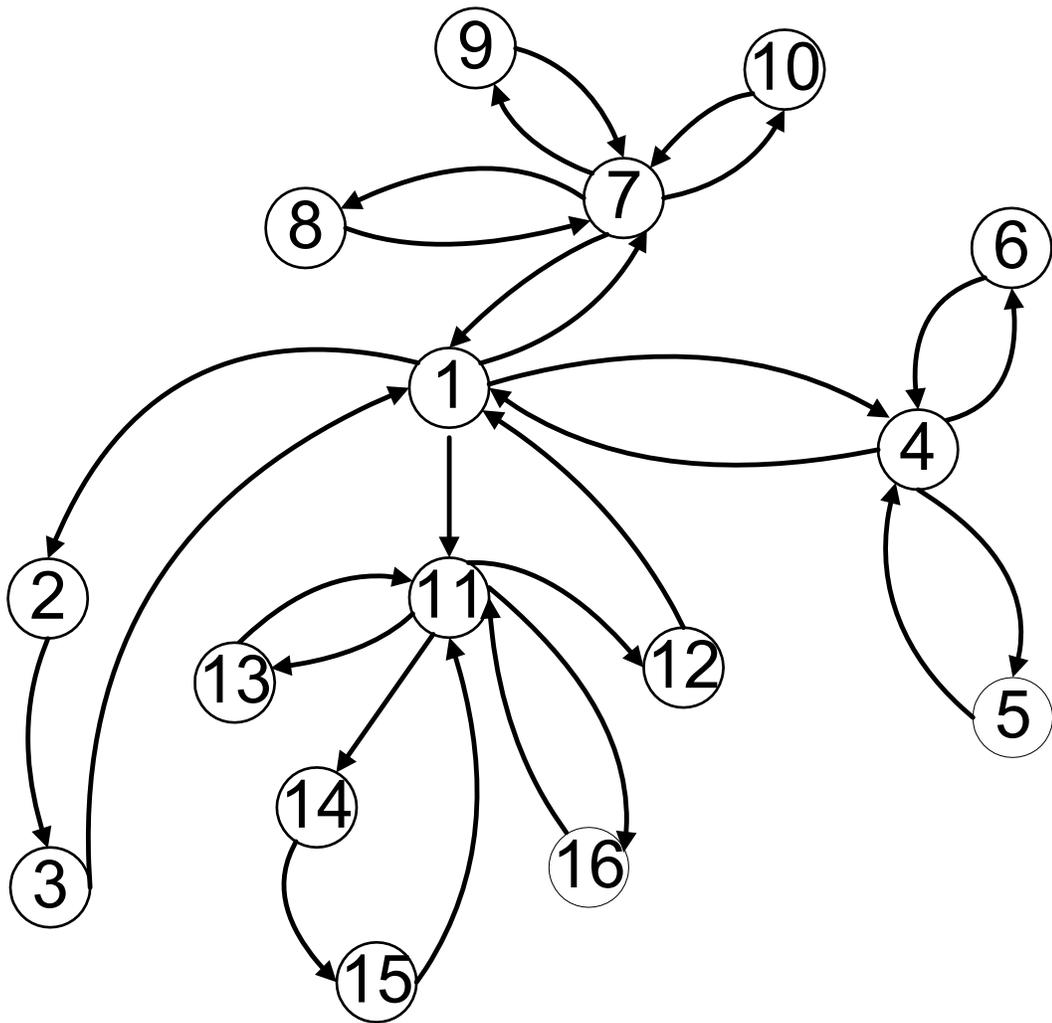


Figure 28: Network with low stratum and high compactness values that represents the information navigation structure generated in solving ill-structured problems

Discussion

Path metrics values could be used to assess the ways in which students navigate through the Internet to appropriate information and apply associated information search strategies in relation to the structuredness of the problem solving task. This has been corroborated by the high degree of reliability of the results obtained from the paired t-test analysis on the path metrics data. The path metrics and corresponding graphical representations of the path diagrams afforded opportunities for gaining richer insights into the information search processes employed by students in cognitively “modeling” the mammoth web space of the Internet and framing appropriate search techniques.

A strong association was found between path metrics and structuredness of problem, with the problem typology having an effect on the values of the computed path metrics values. The quantitative findings from the statistical analysis done in testing the validity of the specified hypotheses substantiate the qualitative research findings elaborated upon in the earlier chapters. This affirms one of the key strengths of a mixed methods research design paradigm where the two approaches of quantitative and qualitative data analysis either serve to mutually inform one another or contribute towards strengthening the findings of either of the orientations. The paired t-test results evidently indicate that successful well-structured problem solving mandates accessing and managing information searching in ways distinctly different from the processes associated with ill-structured problem solving. Students adopted pathways through web space displaying networks of navigation that had high

stratum and low compactness values when it came to solving well-structured problems. On the other hand, students who unraveled ill-structured problems organized their navigations with derivative patterns of movements having low stratum and high compactness values.

The high stratum and low compactness values of the paths undertaken by students who had successfully solved well-structured problem tasks indicated that the navigation styles of these students involved high degrees of linear, structured and deeply embedded movements of information searching. Further substantiating this finding was a visual analysis of a sample path diagram representing the structure of navigation of these students in attending to well-structured problems. The diagram included linear strands denoting sequential, systematic navigational paths that have been traversed by these students.

A well-structured problem is inherently well-defined and bounded. It is characterized by an enveloping information space that is both confined and clearly demarcated. Thus, it was readily easy for students to formulate clear search objectives, efficiently implement planned information searching procedures and organize their search activities to achieve the goals of solving a well-structured problem theme. Their initial search attempts, being exploratory in nature, were essentially 'trial and error' pursuits and thus didn't instantly yield relevant results. However, these attempts gave the students a better cognitive grasp of how they ought to frame their search queries for more narrowed down and precise search output listings to be displayed. Students were then able to locate desired search results that matched their information

requirements. The ensuing search movements involved students visiting systematically the displayed hits and sequentially traversing through the embedded chain of links in the websites to mine out necessary information. Structurally, their patterns of navigation were thus more linear and less connected. Students exhibited a great amount of flexibility in their search orientations and approaches. Since they had been exposed to the variety of search tools available in the Internet, students tended to evaluate the effectiveness of their searches by carrying out their searches with different search engines and accordingly adjusting their actions to achieve the goals of their search.

On the other hand, when it came to tackling ill-structured problems, students registered networks of information navigation routes that were predominantly flatter, more spread out and inter-connectedly linked as highlighted by the sample path diagram – hence, contributing to lower path stratum and higher compactness values.

Ill-structured problems are messier to confront since they do not yield singular, unanimous answers. Without conclusive solutions, learners approaching ill-structured problems need to attend to multiple viewpoints and arguments in justifying their proposed solutions. Furthermore, ill-structured problems are cross-curricular in composition in their content knowledge expertise requirements. The search actions of students in solving ill-structured problems tended to be multi-directional, complexified and iterative. Frequently they had to backtrack to the root search engine web sites by pressing the back button to launch their multiple queries on the different facets of the ill-

structured problem and cover as much information ground as they could in dealing with the multi-disciplinary character of the problem. Thus, students needed to employ the higher order of information search tactics in combination with the basic search skills they had learnt to better monitor, manage and accomplish their search actions. The resultant information search movements generated richly associative patterns of networks that were broader, expansive and distributed in structure.

CHAPTER 8 – CONCLUSIONS

This chapter presents summarily the key research findings of this research study in establishing the influence of different Internet information searching skills and techniques on successfully solving well and ill structured problems. This is followed by a discussion on the pedagogical implications of these findings to improving problem-based learning instructional practices. Finally, further possible studies will be explored as an extension to the work already done in this study.

In this mixed-method study, the researcher set out to examine the mediating effects of Internet information searching capabilities on problem solving cognition of a class of tertiary students in a polytechnic that has adopted a problem-based learning curricular model. A detailed description of students' pre-intervention Internet information searching proficiencies, the training intervention they attended and analysis findings of quantitative and qualitative post-intervention data on the efficacy of different information searching strategies in solving well and ill structured problems has been documented in this thesis.

Problem-based learning (PBL) in essence is an instructional method that challenges students to learn in meaningful ways and work collaboratively towards seeking solutions to authentic real world problem situations. These problems are used to provoke students' interest and initiate students' learning

of relevant subject content matter. Solving problems empowers students to think innovatively, divergently and analytically. The ability to solve problems is intellectually demanding and engages learners in higher-order thinking skills.

This study has established that information searching skills are a strong predictor factor influencing the effectiveness of problem solving performance and shaping the ways in which students deal with problem tasks. Information searching skills indeed are a key function of the ability to successfully solve problems. The results of this study inform that information searching strategies impact problem solving processes including constructing the problem representational space, conceptualizing solutions, evaluating solutions and implementing and monitoring solutions. Information searching competencies are a critical factor in determining the quality of success of problem solving since they actively engage students in identifying the extent of information needs, researching for or creative exploration of answers, executing appropriate search strategies, managing found information efficiently and applying required information effectively. To take full advantage of problem-based learning, students have to use skills requiring them to become proficient users and organizers of information resources found in many different locations and formats, thereby increasing responsibility for their own learning. Information searching particularly becomes problematic in the context of reliance upon the Internet as the dominant source of information access. Though, the Internet is the most comprehensive electronic medium of information hosting in allowing easy reach to instant information, in structure, it is a convoluted web of information resources and unregulated repository of

information posting. Students who are unaware of the complexities involved in Internet navigation and remain untrained in the expertise of information searching will not be able to fully exploit the affordances of the Internet as a problem solving enabler. The findings of this study emphasize the need for students to be consciously and systematically instructed on the taxonomy of relevant information searching strategies that facilitate the accomplishment of positive problem solving outcomes.

However, problem solving is not a generalizable activity. Problems differ either in their content, structure, nature, form and components. Jonassen (1997, 2000) in his writings has explicated on different problem types that can be situated across a continuum spanning from well-structured/routine problems to ill-structured/non-routine problems.

This study has established that students need to examine the nature of a given problem and determine its attributes before defining problem solving strategies and generating possible solutions. Well-structured problems are usually well-defined with the parameters of the problem being specified in the problem statement and knowable correct solutions easily attainable. These problems invoke a limited number of regular concepts, rules and principles organized in a preferred and predictable manner. It was found in this study that a systematic procedural approach comprising of tops-down problem solving strategies is suited to effectively solving well-structured problems. Some of these strategies involve analysing the structure of the problem, identifying and manipulating mediating variables, making conceptual links between the variables and determining the unknowns through the application

of appropriate equations/formulas and mathematical computations. It was also ascertained in this study that the information needs of well-structured problems tend to be constrained, discipline-specific with related information searching to be done in seeking answers easily manageable. This study established that being conversant with fundamental information searching skills involving awareness of various Internet search tools and their differentiated search purposes as well as basic information searching techniques is sufficient for solving well-structured problems. Information searching patterns of navigation associated with successful well-structured problem solving were marked by strands of linearly and sequentially ordered search movements, contributing to high stratum and low compactness values. Hence, these patterns of navigations structurally were more linear and less connected.

On the other hand, ill-structured problems are ill-defined and possess ambiguous goals and multiple possible solution states. There are no general rules, principles or explicit means for determining appropriate actions. There are no easy prototypic or consensual solutions and students need to make learned, personal judgments. It was found in this study that certain problem solving strategies can specifically be employed in tackling ill-structured problem solving. One strategy that was assessed to be effective in solving design problems was that of team brainstorming where students individually brainstorm and list as many ideas as they could generate on the problem theme and then collectively evaluate and select the most relevant ones. Ill-structured problems such as dilemma problems were found to be more easily

solvable when approached from multiple analytical contexts and angles of reasoning to gain a more multi-faceted understanding of issues associated with the problems. Taking into consideration the perspectives and views of different stakeholders was also deemed to be useful in tackling these problems. The information demands of ill-structured problems are both multi-disciplinary and extensive. The research findings of this study inform that to successfully solve ill-structured problems, students need to apply more advanced information searching skills involving framing of essential and foundation research questions as well as developing and organizing search keywords. Information searching patterns associated with ill-structured problem solving were found to be diffusive, expansive and multi-directional. Being flatter and more connected, these networks of search movements were characterized by low stratum and high compactness values.

Implications for teaching practice

The analysis of pre-intervention data from this study demonstrated that participant polytechnic students prior to undertaking the interventionist training programme lacked proficiency in effective Internet information searching skills. This finding is significant and consistent with contemporary scholarship that emphasizes these skills to be non-trivial and complex to be left to be developed intuitively or autonomously by students on their own. Lack of information searching proficiency impedes students' ability to accomplish successful problem solving.

This study's findings suggest the need for students to acquire a formal set of understandings on information searching. Students have to be consciously aware of the suite of information-seeking strategies in relation to the structuredness and complexity of problems in order to become competent information searchers and problem solvers. Students need to be assessed for their information searching proficiencies and those lacking in these skills properly instructed on these skills. The interventionist framework suggested in this study could be used as a template of reference in guiding educators to incorporate appropriate training processes to augment student's information searching and problem solving mastery. Introducing students to the basic information searching skills explicated in this framework on learning about Internet search tools and fundamental search strategies and techniques such as the use of Boolean operators would equip students with necessary foundational skills in performing well-structured problem solving. Building upon these elementary competencies, students could then be taught on more advanced information searching skills involving framing of essential and subsidiary research questions as well as developing and organizing search keywords to be able to apply these skills to solve well-structured problem situations. In engaging in problem-solving, being aware of the functional utility of these skills allows students to select and execute the appropriate ones based upon an analytical evaluation of the degree of structuredness, prescriptiveness and abstractness of the problem.

With the Internet having nearly become a permanent and ubiquitous fixture in the increasingly technological landscape of present day education, Internet information search literacy expertise in terms of locating, abstracting, comprehending and using digital information is a core pedagogical competency. These skills cannot be assumed to be already possessed by students through self-directed modes of acquisition or be completely ignored in the instructional design of formal curriculum. Students need to be systematically instructed on these skills. Orienting students to the skills of information searching ensures that they do not arbitrarily jump into a problem-based learning task without planning for a proper search. Students are then able to reflect upon the complexities of the problem tasks they need to solve and be able to cognitively model effective plans of information searching and decision making.

Such an investment in training will not go in vain since educational institutions are now no longer able to teach all knowledge content that students need to know in order to function adeptly in the outside working world. Rather, students need to be coached on the adaptive processes of learning how to learn and learning to competently search for and utilize new information to build up knowledge schemas. In short, instructionally preparing students to become expert information searchers prepares them to function adaptively in the emergent educational environment of transformative learning and problem solving.

Further research

This study investigated the Internet information searching proficiencies of a class of polytechnic students in Singapore pursuing intellectual excellence through a problem-based learning methodology. There also arises a need to research on the information search knowledge and competencies of the polytechnic's academic facilitators themselves. For an instructional program aimed at improving students' information searching skills to be mounted with success, first and foremost, teachers themselves need to be competent in these skills to be able to effectively impart them to students. Schwartz (1998) posited that most adults themselves were novice searchers. So it is important to assess teachers' digital information literacy capabilities and if necessary, adequately address any shortcomings through staff developmental workshops.

This study examined the treatment effects of a set of information searching skills and strategies upon students' problem solving performance and outcomes. In this study the problem themes that were used were broadly classified as either well or ill structured problems. Further research needs to be conducted to investigate on the influencing impact of these information searching skills on each of the different problems types within the well and ill structured problem classification typology delineated by Jonassen. Well-structured problem types include logical, story and rule-using problems whereas ill-structured problem types include troubleshooting, diagnosis-solution and situated case problems. The mediating influence of information searching skills in engaging in solving each of these specific problem types warrants further research. Associated problem solving strategies that students

could apply to successfully deconstruct and solve each of these problem types also requires further investigation. Moreover, the treatment effects of information searching skills in combination with other predictor skills such as domain-specific disciplinary knowledge and metacognitive dispositions on problem solving achievement could also be probed deeper.

Information literacy is a wide field of expertise constitutive of a number of highly specialized skills. Notably, amongst these skills, information searching is a crucial competency and has been the focus of this study. However, mastery of other information literacy skills such as information processing, application and evaluation is equally important in realizing positive problem solving outcomes. Due to various constraints such as time limitations, these other aspects of information literacy have not been covered within the research scope of this study. This is yet another possible rich area of extended research that be actively explored.

APPENDIX A: Pre-Intervention Survey

(Space was provided for students to answer each question)

- 1) How did you learn to use the Internet?

- 2) Do you plan your search before actually carrying it out in the Internet? If so, how do you do it?

- 3) Which search tools do you use to find information in the Internet? Give reasons in explaining your choices.

- 4) When using search engines, which search engines do you normally prefer to use? Why so?

- 5) Do you use multiple search engines in doing your information searching? Why so?

- 6) Do you think there are any similarities/differences in the ways different search engines work? What would they be?

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