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# Mixed Methodology Research Design in Educational Technology

*In recent times many educational researchers have moved away from the traditional purist approach of strictly adopting either a qualitative or quantitative approach to conducting research. Instead they have attempted an eclectic mix of both methods in their research inquiry, combining aspects of both the traditions at various stages of their experimental study such as in the formulation of research questions/hypotheses, design of research methods, analysis of data, and discussion of research findings. Such integration harnesses the strengths of both traditions and underpins a methodologically sound research design. In this article the author recounts details of how a case study anchored to principles of mixed methodology research design was carried out.*

*Ces derniers temps, plusieurs chercheurs en éducation se sont éloignés de la tradition puriste selon laquelle l'on adopte formellement une approche qualitative ou quantitative à la recherche. Ceux-ci optent plutôt pour un mélange éclectique des deux méthodes qui combine des aspects des deux traditions à diverses étapes de leur étude expérimentale, comme lors de la formulation de leurs questions ou leurs hypothèses de recherche, la conception de leurs méthodes de recherche, l'analyse des données et la discussion des résultats de recherche. Une telle intégration s'appuie sur la force des deux traditions et sous-tend une conception de recherche qui est solidement établie sur le plan de la méthodologie. Dans cet article, l'auteur explique le déroulement d'une étude de cas reposant sur des principes d'une méthodologie de recherche mixte.*

## *Background of the Study*

The Internet offers great promise as a powerful tool that can be integrated into curriculum and instruction to enhance education. It provides access to a set of tools that could improve teaching effectiveness. It hosts a vast array of online educational resources that enrich learning by stimulating students to think both concretely and abstractly; to help them make constructive connections to real-world applications; to build new skills and knowledge; and to reason, critique, and question.

In Singapore there has been an increasing emphasis on the use of technology, and in particular the Internet, in schools in efforts to encourage innovation in teaching approaches and heighten students' motivation to learn. All schools in Singapore are connected to the global digital highways of the Internet and have extensive hardware and infrastructure facilities in place in order to support Internet-based learning activities. Many schools have reported widespread access of their Internet facilities both during and after school hours.

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However, a review of the existing literature reveals that pervasive usage of Internet technology alone does not guarantee positive gains in instructional objectives. Technology can play only a peripheral role in scaffolding pedagogical processes. The heart of learning lies in effective instructional strategies that efficiently manage diverse educational provisions to optimize students' learning outcomes.

Thus it was timely that a critical analysis of students' current Internet information skill levels be conducted. A case study of students' Internet information literacy practices in seven schools in Singapore was carried out to provide baseline data for the analysis. The primary goal of this case study was to examine holistically students' current Internet information searching and navigation skills. Largely using qualitative data in the form of video-screen excerpts of students' online movements, a mixed-methodology research design that integrated qualitative and quantitative research methods was adopted as the best approach to achieving this goal.

*Literature Review*

With the current focus on creating a society of lifelong learners, it is important that students learn to find, comprehend, evaluate, and appropriately use information that is continually changing to enhance their learning. The arrival of the Information Age has created an important literacy necessary for students to be successful in this ever-changing world, that is, information literacy (Roth, 1999). Electronic media and communication tools have emerged as key players in shaping the field of information literacy. In particular, the Internet offers great potential as a versatile information literacy tool.

An understanding of how Web users interact with the Internet in navigating their paths through its morass of information to locate and make sense of the gathered information to build new knowledge could markedly affect pedagogical decisions about the use of information in educational systems. Gathering and analyzing information found in the Internet calls for a complex set of skills that are not easily mastered (Nachiamas & Gilad, 2002).

This finding reinforces the understanding that the Internet is a complex, interwoven network of ill-defined information, which makes it difficult to search for information. Effective searching skills to locate timely information and make meaning of it are challenging and not trivial. Tyner (1998) warns that predominantly at the secondary-school level, where the application of technology to instruction is often a vital school reform component, the focus still seems to be on hardware rather than on developing the cognitive skills needed for efficiently locating, understanding, and using information to aid in decision-making and problem-solving. Tapping the potential of the Internet and the wealth of educational resources it holds requires concerted efforts by educational policy-makers, curriculum planners, and teachers to gauge students' proficiencies in using the Internet. This will facilitate the design of appropriate Internet-based learning activities with sufficient instructional scaffoldings. Surprisingly, little research has been conducted, especially in the Singapore context, on the Internet searching and navigation practices of students to inform policy-makers and other stakeholders about these issues.

The small amount of international research that has been conducted reveals that most existing Internet-based instructional programs in schools are ill

designed and not developed based on a theory-based instructional design process (Marcum, 2002). For Internet-based instructional programs to be effective, they must be theory-based and organized in a cycle of instructional design activities with clearly defined stages. The first step in designing such programs is to determine students' current proficiencies in searching the Internet for information and learning from it. Such a needs analysis would identify discrepancies between current skill levels and the skill levels needed to improve students' skills and bridge the gap between the two (Kemp, 2000). Then appropriate scaffoldings and mediation could be incorporated into the program design (Stern, 2002).

*Research Design*

A *mixed methodology research design* (Creswell, 1994) was adopted for the purposes of this study. Such an integrated approach maximally combines both qualitative and quantitative research protocols. The researcher combines aspects of the qualitative and quantitative paradigm through all or many methodological steps in the design. Such a combination of methods could be used in the introduction, in the literature review and theory use, in crafting research questions, and in formulating data collection and analysis methods. This approach adds complexity to the design and research processes by harnessing the advantages of both qualitative and quantitative research methods. The overall design holistically incorporates inductive and deductive models of thinking involved in research studies (Creswell, 1994). Tashakkori and Teddlie (1998) have termed Creswell's label *mixed methodology design* as *mixed model studies* and proffer a slightly different description of it, although the orientation remains the same: "Studies that are products of the pragmatist paradigm and that combine the qualitative and quantitative approaches within different phases of the research process" (p. 19).

Rossman and Wilson (1985) explicate that the three advantages of mixed method studies are corroboration, elaboration, and initiation. Corroboration is the "convergence in findings"; elaboration "provides richness and detail"; and initiation "turns ideas around." Gibson and Duncan (2002) added another benefit to this list, that of reconciliation. Reconciliation seeks to resolve contradictory findings.

Greene, Caracelli, and Graham (1989) advanced five purposes for combining methods in a single study.

- Triangulation to seek convergence of results;
- Complementary in that overlapping and different facets of a phenomenon may emerge;
- Developmentally, wherein the first method is used sequentially to help inform the second method;
- Initiation, wherein contradictions and fresh perspectives emerge;
- Expansion, wherein the mixed methods add scope and breadth to a study.

In operationalizing this research study, a mix of qualitative and quantitative methods was used in various phases to gain a deeper and richer understanding of the issues being investigated. In qualitative studies, normally both theory and literature use are carried out inductively with an emerging design guiding the framing of the problem. On the other hand, in quantitative studies theory and literature are used deductively to develop the research questions (Cres-

well, 1994). In the mixed methodology design approach employed in 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 advancing research questions and hypotheses, descriptive, broad-based, exploratory research questions were asked in language befitting the design characteristics of qualitative research, whereas hypotheses were postulated to test relationships between measurable variables in alignment with the requirements of quantitative research methods. Hence elements of both research paradigms were melded to present a mixed methodology approach in the formulation of research hypotheses and research questions. As for methods of data collection, qualitative data were gathered predominantly in the form of video-screen outtakes of students' Web activity and online interactions, as well as the artifacts they assembled in their efforts to complete the assignment. However, data analysis involved a mix of both qualitative and quantitative methods respectively, using content analysis informed by emerging themes and statistical analysis of quantifiable constructs. This helped to ensure congruence and consistency of the findings, which are presented at the end of the article.

*Ensuring Trustworthiness*

*Triangulation.* Both qualitative and quantitative methods were used, which resulted in a mixed methodology design. This allowed for triangulation of both data and research methods, thus improving the reliability and trustworthiness of the conclusions. Triangulation prevents a researcher from accepting too readily the validity of initial impressions and contributes to verification and validation of analysis by checking consistency of findings generated by varying research methods and varying data sources in the same method (Burns, 2000). The concept of triangulation is based on the assumption that any bias due to exclusive reliance of one method or particular data sources can be rectified by using other data sources and alternative methods. Triangulation allows the shortcomings of one method to be offset by the strengths of another. It also provides greater opportunities for causal inference (Brewer & Hunter, 1989).

*Persistent observation.* We relied heavily on persistent observation as a technique during both the data collection and analysis phases of this study to improve the trustworthiness of inquiry and findings. Tashakkori and Teddlie (1998) posit that the purpose of persistent observation is to provide *depth* to help researchers to identify the characteristics or aspects of the research setting that are most salient and relevant to the questions being pursued.

## *Data Collection*

*Data Source*

A stratified purposive sampling technique was used to select the schools involved in this study. Stratified sampling is generally used when the sample size is small and the proportion of subgroups (strata) in the population are known (Tashakkori & Teddlie, 1998). Students from a total of seven schools in Singapore formed the sample. Because of logistical, manpower, and scheduling constraints, a larger number of schools could not be recruited for the study. Therefore, stratified nonrandom sampling procedures were adopted in order to draw a more representative sample of the population. The schools selected

for the study varied academically, ranging on a continuum from schools that were performing well academically to those schools that were lagging behind the national average. These schools also contrasted markedly in their instructional technology (IT) skills curriculum profiles and differed in their approaches to implementing IT enrichment programs for their students. Thus students who participated in the study varied in their IT knowledge and abilities.

However, the students in each school were randomly selected by their teachers to participate voluntarily in the study. Thus a mixture of both random and nonrandom sampling methods was used because such an approach fits well with the underpinning objectives of a mixed methodology research design model.

*Information Problem-Solving Task*

The recommended textbooks for the Secondary One Science syllabus discuss briefly in the chapter "Measurement of Length" how measuring instruments such as vernier calipers and micrometer screw gauges can be used. Situated cognition suggests that knowledge needs to be contextually situated, and it is fundamentally influenced by the given activity, context, and culture (Kirschner & Whitson, 1997). With this constructivist learning dimension in mind, the learning task was framed by instructing students to search the Internet to find out the industrial applications of vernier calipers and micrometer screw gauges. The purpose was clear in that the most relevant information needs to be found in the least amount of time. However, multiple search strategies are possible, which allows the problem to be slightly ill structured. When the students had successfully located relevant resources online, they had to construct artifacts to demonstrate their learning. In the process, students needed to glean meaning from the information found in the resources, make judgments about the relevance of the information, and finally synthesize appropriate information. Students were given the option to use either Microsoft Word or PowerPoint to construct their digital products.

*Materials*

*Macintosh Powerbook G4s*. A Mac Powerbook G4 was assigned to each pair of students to execute their Internet searches and construct their artifacts. Each of these Powerbooks was configured with a Safari to facilitate students' surfing of the World Wide Web to access informational resources. The Safari browser was also loaded with a menu bar offering a selection option of links to three popular search engines and one meta-search engine respectively: Yahoo! Google, Excite, and Mamma. This scaffolding was intended to aid less Internet-savvy students who might otherwise not know the URL addresses of common search engines and be able to access them on their own. However, students were clearly instructed at the onset of the task that they were free to access any search engine of their choice in mapping their information search trajectories.

*SnapzPro X 2*. Each of the Mac powerbooks was installed with the screen-capturing software SnapzPro X 2. This sophisticated software expertly records full-motion video of all screen movements quickly and is complete with digital audio and an optional microphone voice-over. The research team used the voice-recording feature available to capture students' talk about how best they

should approach solving the task problem. These audio-recordings served as think-aloud protocols to trace students' thoughts and cognitive processes in their collaborative attempts to navigate and extract relevant information. SnapzPro was thus a powerful tool that worked well as a kind of digital video camera in documenting students' online activities on the Macs.

*Procedure*

Invitation letters were sent to secondary schools to participate in the study, and seven schools that replied in the affirmative were listed to be involved in the study. Teachers in the participant schools were requested to nominate student volunteers for the data collection sessions.

Schedules were worked out with the teachers in charge in the participant schools to allow the researchers to conduct the research experiment sessions with the students after school. Before the start of each experiment session, students were given a brief 10-minute overview of the basic functions of Macintosh system and features of the Safari browser, the default Web browser in Macintosh machines, to surf the Internet. System procedures such as how to drag pictures from the browser window to the desktop and from the desktop to the artifact-constructing software and copy text from the content in the browser window to the artifact-constructing software were demonstrated to the students. They were also familiarized with navigation features in the Safari environment such as moving forward and backward between browser windows. Then the task worksheets were distributed to the students, and each pair was assigned to a Macintosh powerbook. Students were instructed to go through the requirements of the assigned task and clear any doubts they might have. Then each pair was allocated 30 minutes to complete the information problem-solving task.

When the students were ready to begin their task, the researchers activated SnapzPro software and the voice-recording function to capture students' online work and thought processes. To ensure uniform experimental conditions, the researchers and technical assistants present throughout the course of the session offered no assistance to the students.

At the end of the stipulated 30 minutes, the recording of students' Web movements was halted and the processing carried out to obtain video-recordings in Quicktime movie digital format. The corresponding artifacts made by the students were saved and stored to be analyzed later. The blank papers given to the students at the start of the experiment to express in writing their tactics and Web search rationales were also collected.

## *Data Coding Procedures*

*Defining Units of Analysis*

Screen capture recordings of SnapzPro were analyzed to chunk and parse the students' Web interaction data in terms of codes that were central to the focus of the research methodology. Operationally chunking raw data means identifying it into meaningful units or nodes of analysis (Barab, Hay, & Yamagata-Lynch, 2001). Miles and Huberman (1984) defined nodes as time-dependent events that "happen" (a meeting, a conversation, or a mouse click), or they can be defined as a state of mind (student frustration or pressure by parents). In their research approach, Barab et al. considered nodes as equivalent to what

qualitative researchers have described as *units, chunks of meaning,* or *ethnographic chunks* (Jordan & Henderson, 1995; Lincoln & Guba, 1985). These nodes or units are identified as activity occurrences that are judged to be significant in the learning context and are delimited by a change in theme, activity, subject, or resources. This criterion is consistent with the ideas of Jordan and Henderson in selecting ethnographic chunks for interaction analysis. Chunks that are transitions from one segment of an event to another are often indicated by shifts in activity, heralded by changes in personnel, movement of participants in space, or the introduction and manipulation of new objects.

What qualifies as a significant shift in segment is subjective and thus must be considered aligned to the needs of the research context and the phenomenon under investigation (Barab et al., 2001). Lincoln and Guba (1985) suggested two criteria for selecting units of analysis. They must be heuristic and must be the smallest piece of information about something that can stand by itself. Lincoln and Guba's description of the second criterion for a unit of analysis is to select the smallest piece of meaningful information, a grain that as mentioned above, is somewhat subjective and dependent on the context of the research requirements and interests of the researcher. For example, it could be capturing fine-grained actions (e.g., mouse clicks or turn-taking in a conversation) or more molar units (e.g., moving an object across a screen or planning a discussion). Lincoln and Guba's two criteria were used in carefully defining what constitutes meaningful and significant units of analysis for this study.

*Building Codes for Units of Analysis*

A principal step in the research methodology involves conventions for developing codes to label the units of analysis discussed above. Instead of predefining a set of fixed codes that are then applied rigidly in the analysis of screen-capture recordings, a more flexible approach was adopted for coding the raw data. Through repeated observation and analysis, codes of key actions and online events emerged and were documented. Thus the development of the coding types was an evolving and iterative process that was constructed over a significant period during the research study (Glaser & Strauss, 1967). The raw data and emergent interpretations of codes interacted dialectically, each reciprocally informing and being informed by the other. Units of analysis coded for included meaningful micro-events such as mouse clicks or keying words using the keyboard that indicated a movement or shift in activity with a significant effect on learning. Other examples of coded finer grains of purposeful activities included viewing a new Web page in the window browser, accessing a Web link to move from one Web page to another, and executing keyword searches using popular search engines. More molar units of actions such as dragging a graphic from the Internet Web browser window to the desktop and then from the desktop to the artifact-construction software such as Microsoft Word were also coded.

These codes were conceptualized and created on the fly on careful observation and investigation of each recording and captured in an Excel database. A column was created in the database to list when the temporal sequence of significant events occurred, and another column was inserted to enter the codes for these events. Yet another column was generated alongside this

column of codes and labeled *descriptions* to enter rich comments on the texture of these codes. Because the codes were limited in size to keep them succinct and precise, the field of descriptions allowed me to record thick details on the nature of the codes and the multiple contexts of their meanings and applications.

### *Research Hypotheses and Questions*

In advancing research questions and hypotheses for this study, two hypotheses were formulated to analyze quantitatively constructs and test relationships between variables. One descriptive, broad-based, exploratory research question was also asked in language befitting the design characteristics of the qualitative research approach.

#### *Quantitative Research Hypotheses*

The proposed hypotheses to be tested through quantitative analysis are as follows.

1. The path compactness metric is negatively correlated to students' performance outcomes in a problem-solving learning task.
2. The path stratum metric is positively correlated to students' performance outcomes in a problem-solving learning task.

#### *Explanation of Metric Variables and Rationale for Hypotheses*

Much interest has been generated about wishing to develop a better understanding of users' Web behaviors and patterns of interactions in a hypertext environment. Many studies conducted in this domain have employed "static" measures related to the number of nodes or accessed links, the number of times particular Web browser function buttons were clicked, or measures of time and path length (Qiu, 1994; Schroeder & Grabowski, 1995). Besides such static data analysis, a more dynamic and spatial representation of Web movements can be realized using navigational paths as data (McEneany, 2001). The popularity of path navigational analysis is principally due to the nature of a path in its being the most complete measure of user navigation. Such an analysis affords an understanding of the encountered search processes and the strategies users apply in acquiring information (Lawless & Kulikowich, 1996). Thus this approach is a powerful data-collection and analysis tool that serves well for empirical investigators.

McEneaney (1999, 2001), in his important study, analyzed the characteristics of users' paths by relying on path-specific structural metrics. He developed his framework of path analysis based on the structural analysis of hypertexts originally conceptualized by Botafogo, Rivlin, and Shneiderman (1992). This framework developed to assess and visualize users' navigation is similar to the historical node-and-link model of hypertext. The two structural metrics McEneaney uses to quantify navigational path data are compactness and stratum. These metrics are respectively indicators of the complexity and connectedness of network-based structures defining users' online navigational visits. The characteristics of complexity and connectedness in turn will provide insight into some of the properties of users' Web movements.

Compactness refers to the overall connectedness of a network of nodes accessed with more sparsely linked networks resulting in values for compactness close to 0, whereas densely connected networks yield compactness closer

to 1. Thus a high compactness indicates that each node in the network can easily reach any other node in the network structure due to a large number of cross-referencing links (Botafogo et al., 1992).

On the other hand, stratum indicates the degree of linearity of a network of nodes visited and shows the extent to which a network is organized so that certain nodes must be read before others. Stratum also ranges between 0 and 1, with more linear (hierarchical) networks with fewer cross-referencing links between the nodes having stratum values tending closer to 1, whereas more web-like networks with a large number of cross-referencing links have stratum values slanting toward 0. Figure 1 shows path diagrams adapted from McEneaney (2001) that graphically illustrate two networks with radically different stratum values. The first is a linear and highly structured network with a stratum value of 1; and the second is a closed cycle or path with little hierarchy and structure, thus having a stratum value of 0.

The quantitative aspect of my study aims to study the relationship between students' navigation patterns as measured by the metrics of stratum and compactness against their performance in an information problem-solving task. I postulated that students who perform well by scoring highly in their assigned information-seeking task would traverse Web space in networks of navigational pathways that have low values for the path compactness metric. Conversely, the characteristics of these structural networks would reflect high values for the path stratum metric. These conjectures are based on the presupposition that students who are successful in their task would possess competent information-searching skills that translate into efficiently narrowing down the list of relevant Web sites to be systematically browsed to look for appropriate information. These students are expertly able to locate accurate Internet sources of information and are expected to traverse each of these paths deeply in search of information and move sequentially through embedded links to exhibit more hierarchical, linearly ordered, and less connected patterns of navigation.

On the other hand, students with a poor fund of information-search strategies tend to have a more dispersed and distributed style of navigation

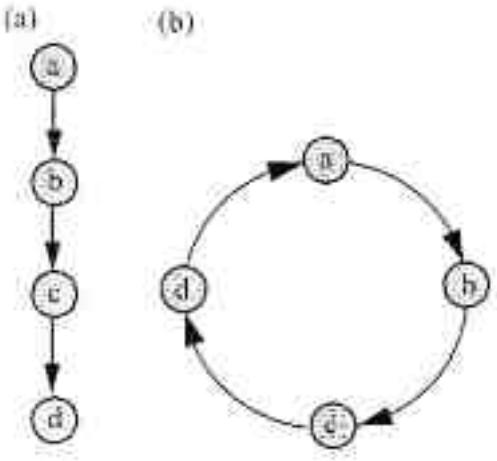


*Figure 1.*

involving accessing a large number of Web sites and traversing a host of cross-referencing links in them in unplanned and haphazard searching for information. Such navigational patterns contribute to more connected and less structured networks. These networks, then, would tend to have high values for path compactness metrics and low values for path stratum metrics.

*Qualitative Research Question*

The following research question would be qualitatively investigated through descriptive content analysis: What are the differences in characteristics of Web-searching behaviors between a student who has a positive performance outcome in an information problem-solving task and one who is unsuccessful in the same task?

*Qualitative Analysis Strategies*

A case study approach was adopted as the best means to examine qualitatively the above research question. One case of a student who was successful in the information problem-solving task was selected and compared with the case of a student who underperformed in the task. This facilitated the analytical study of structural differences between both students in terms of Web navigational behaviors and search strategies. A case study by definition constitutes an exploration of a *bounded system* (or a case or multiple cases) over time through detailed, in-depth data-collection involving multiple sources of information rich in context (Creswell, 1994).

A particular case is generally selected not because it is representative of some population, but because it serves the real purpose and objectives of discovering, probing deeply, gaining rigorous insight, and understanding a particularly chosen phenomenon. Such a case study would be valuable in its own right as a unique case (Burns, 2000). The two cases that were selected in this study were purposive and chosen to draw the maximum of what can be learned in the amount of time allocated. The choice of the cases earmarked for analysis was also informed by Stake's (1998) assertion that cases are not generally chosen for typicality or for their ability to generalize to other cases or situations. Rather, cases are often selected because they are accessible and increase opportunities to learn from them.

## *Conclusion*

The Internet is a technological tool with the potential to improve instructional practices. This is due to the large number of educational and information resources that it offers for both teachers and students. These resources can be accessed flexibly and at one's own pace. The Internet thus empowers student-centered learning. However, the effective design of Internet-based instructional programs is predicated on the evaluation of students' current Internet information-searching and navigation skills. The empirical case study discussed here assesses a group of Singapore students' on their Internet information proficiency skills. In conceptualizing the design for this study, a mixed research design approach was determined and adopted as the most robust research framework. Such an approach ensures deeper insights into the issues being scrutinized and enables multiple angles of analysis through employing a variety of quantitative and qualitative means of inquiry.

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