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Abstract— **Researchers report that learners find the flexibility of hypermedia learning systems both a strength and a weakness. On the one hand, the systems allow learners to work at their own pace and allow a great deal of control of the learning paths they take. For some learners this is a blessing, bur others feel overwhelmed by the large number of available option and suffer from information overload. One approach to this is to provide learners with an adaptive learning system that initially limits the choices they can make until they mastered they key concepts. During the study, *ART-WEB* was used to develop a prototype of an adaptive web-based learning environment. The purpose of the prototype was to provide students with a conceptual and procedural knowledge introduction to the multimedia authoring tool *HyperStudio*. This prototype was trialed with 2 undergraduate and 1 graduate classes. Data were collected by means of questionnaires, interviews, and tracking files of learner use. Coded data were entered into a spreadsheet and then analyzed. The findings showed that the use of adaptive annotation technology supported student learning of basic conceptual and procedural knowledge about the use of the authoring tool. The data suggest that the system provided learners with a well-structured navigation system that made use of textual and visual cues to locate them in hyperspace and to provide feedback on their progress. This supports the findings of other researchers who used the tools in other contexts. This study contributes to the research literatures by showing that web-based learning environments may have a role to play in supporting the development of learner conceptual and procedural knowledge when they are involved in learning a complex skill such as then use of multimedia authoring tool. The tool developed was a prototype and as such would need additional development before being put to general use. However, it did demonstrate a concept and show that such tools may be useful supports in complex, hypermedia learning system.**

Keywords-flexibility, web-based learning environment, adaptive annotation technology, conceptual knowledge, procedural knowledge

I. INTRODUCTION

The use of the World Wide Web (henceforth Web) in educational settings seemed to increase exponentially [11, 18, 20], as it appeared to be a powerful medium for delivery of grounded learning environments [12]. Moreover, it is indicated that the Web and the links with the Internet can aid learning processes. Potential benefits to learners include richer and more effective learning resources and more flexible pace of learning. Provided that the medium is available to them, learners may access rich learning resources at anytime and anywhere and they may pursue a sequence of learning entirely according to their own needs.

Advances in Web technology also can provide a number of learning experiences that go beyond that possible in the traditional classroom environment such as facilitation of variety of learning activities including small group discussion and collaborative projects and a forum for expression of different beliefs and attitudes [8]. It is argued also that such learning experiences are considered as important factors in the facilitation of knowledge construction.

The flexibility of hypermedia system of well-designed learning environments often reflects the interrelatedness and ill-defined or unstructured characteristics of knowledge domains. Such environments could provide rich contextual structures for the acquisition of advanced knowledge [5, 16]. Ill-defined or unstructured domains refer to those which involve concept and case complexity and involve across-case irregularity. Examples of the domain include medicine, history, literary interpretation, advanced mathematics, and all area where at the advanced level there are no clear-cut right or wrong answers.

Research into flexibility of hypermedia systems as an information delivery agent has documented the existence of four problems associated with the use of hypermedia: disorientation, cognitive overload, discontinuous flow, and content readiness [10]. Disorientation refers to users not knowing where they are, where they have been, or how to get where they want to go in the hypermedia space. Cognitive overload refers to users being overwhelmed or confused by options available to them in multi-path, multi-tool environments such as hypermedia documents. Discontinuous flow is divided into two issues: narrative flow and conceptual flow. Narrative flow refers to didactical or dialogical flow of the text itself. Conceptual flow refers to the flow of ideas or concepts. Content readiness refers to how the content is tailored so that the user is neither bored nor overwhelmed. Complexity of non-linear structures of hypermedia also causes inconvenience to users as often the existing navigational tools of hypermedia systems are not powerful enough to provide orientation [2].

Adaptivity is one way to increase the functionality of hypermedia. Adaptive hypermedia is a possible remedy to

the negative effects of the traditional 'one-size-fits-all' approach of many hypermedia systems. Adaptive educational hypermedia or learning systems are capable of recognizing specific user characteristics such as need, background knowledge, and preferred learning styles and respond accordingly [19]. In adaptive systems, the systems responses are performed by tailoring learning strategies and learning materials to meet the individual learner. Thus, a possible way to achieve the adaptivity is by modeling the users and tailoring the system's interactions to user's characteristics. Searching and surfing on the Internet, however, has shown that most hypermedia systems, particularly web-based learning environments, have not been equipped with such adaptivity. It will be beneficial if research that investigates on how adaptivity can be added to web-based learning environments is pursued.

The purpose of the study is to develop and evaluate a prototype of an adaptive web-based learning environment, called *HyperIntro*. The prototype aimed to provide learning support for students as they were developing knowledge about the use of a multimedia authoring tool, *HyperStudio*. It was designed to support learners as they acquired conceptual and procedural knowledge about the use of *HyperStudio*. Thus the focus of the study was to evaluate the effectiveness of *HyperIntro* as a learning support tool. Adaptive annotation link technology has been used to provide adaptation in the design and early development of the prototype. This technology has been promising for adaptive navigation support, which is a collection of all methods of altering visible links to support hyperspace navigation in educational hypermedia [2, 19].

II. METHODOLOGY

This part describes how the study was designed and implemented. It describes research design adopted and the methods of data collection and analysis.

The main research questions for the study are in what ways did the use of the prototype support learners to develop conceptual and procedural knowledge and in what ways it supported their learning. The research was conducted in a setting where the participants were involved in the various processes associated with and assessment task in their subjects, so it was naturalistic inquiry. During the design and development of multimedia projects, the participants needed to effectively use the authoring tool, *HyperStudio*. The prototype was developed to support them in learning the authoring tool, particularly in acquiring conceptual and procedural knowledge of main and basic concepts about using the tool.

In order to overcome history bias, the major inherent of one group pretest and posttest design [17], three groups separate-sample pretest-posttest design complemented by a case study design was employed to describe how the prototype was used.

The main participants were a group of forty-six postgraduates and undergraduates who were enrolling in one of Information Technology core and elective subjects. Selection of the participants can be considered as a purposive sampling [1] instead of random sampling since the participants were identified and selected in accordance with some purposive principle, such as accessibility and ethical consideration, and to obtain the specific information that was relevant to the purpose of the study. Since the samples drawn from the populations are not random samples, then any conclusion drawn from the study would not be generalizable to large population. The collated data were analyzed inductively from bottom up, from many pieces that interconnected, in attempts to develop further understanding on how the learning environment was used.

Furthermore, the strategies used for data collection chronologically are informal interviews with instructors, pretest, informal observation on using the prototype, posttest and questionnaires, and interviews. The use of multiple data collection strategies, multiple sources, and various data types are the bases for triangulating the data in this study. Triangulation refers to a process carried out with respect to data in which a datum or item of information derived from one source or by one method is checked against other sources or by other methods. This process is supposed to test a finding by showing whether independent measures of it agree with it or, at least, do not contradict it [9]. It is aimed at obtaining a judgment of the accuracy of the item. This process was used to strengthen the credibility of findings. Qualitative text responses and quantitative self-rating responses collected from the questionnaires were double-and cross checked with the recorded information gathered from interviews.

Basic information about the participants and the subject outlines was obtained from prolonged interviews with the instructors. These interviews focused on what basic knowledge was needed by the students to effectively use the authoring tool. In addition, a plan was formulated on how to structure the support material. It also helped to clarify keys issues in the design of the prototype such as appropriate level of language used, graphics, and user interface.

In order to find out initial information about participant's conceptual and procedural knowledge about using the authoring tool pretest was employed. The test was in the form of objective-dichotomous self-rating questions. This form was selected since it enables the researcher to develop some judgment and relative measure of learning outcomes such as knowledge about concepts or principles and knowledge about procedures or methods [4, 6].

After the administration of the pretest, the participants were introduced to the prototype. Short but clear explanation on what they were expected to do were given in written and oral form by the researcher. During their attempts to use the prototype as a learning environment, naturalistic informal observations were conducted. Notes were taken from the observations of several participants who were volunteered to assist in this way. The notes described the performance of the participants such as their attempts to make notes, attempting exercises, small group discussion and their comments.

Once participants finished using the prototype, a posttest was administered. The posttest items were the same as those

used in the pretest. In addition, a questionnaire was used. The Likert scale and open-ended form questionnaire asked the participants to respond about educational uses of the prototype such as user consideration, subject content, instructional value, aid in learning, visual design, ease of use, and adaptability. Participant's comments on how the prototype helped them to acquire conceptual and procedural knowledge, whether the adaptive annotation technology helped their learning, and whether the approach adopted in the prototype could be used in other contexts were also collected.

Open-ended interviews were conducted with volunteered participants. The procedure was selected as it can be used to obtain a great deal of information and it is flexible and adaptable to individual situations [7]. The interviews were carried out in order to clarify participants' responses from previous data collection stages, to focus the responses, to expand information gathered from previous responses, and to verify data already gathered.

The collected data were carefully examined again to identify emerging themes. As each set of the data was examined, keywords, phrases, patterns of behavior, subject's ways of thinking, and repeated events were identified. Since this study involved a vast amount of data from multiple sources, a coding system of data was employed. Coding is the term to describe the translation of question response and respondent information to specific categories for the purpose of analysis [7]. A coding system is a means of recording the occurrence of specific preselected behaviours as they happen – a set of categories into which ongoing behavior is classified [1, 17].

Data about each participant's initial knowledge and after-treatment knowledge are ordinal type as they were yes/no response [7]. They were coded or assigned an ordinal scale measurement. To test whether there was a significant difference between participant's initial and post-treatment knowledge (that is there is a significant effect of learning using adaptive learning environment) a non-parametric test, the Wilcoxon Signed-Ranked test [15] was employed on every sample. This test is not bound by the restrictions of the t-test (its parametric counterpart) such as assumption of normality, homogeneity of variance [17] continuity and equal interval of measures, or independence of observations [7].

III. RESULTS

This section is organized into two major parts that relate to the research questions. These are learner use of adaptive learning environments and the use of adaptive annotation technology.

Learner Use of Adaptive Learning Environment

The question addresses is in what ways did then use of the prototype support learners to acquire conceptual and procedural knowledge. A quantitative approach was taken to this question. First, the quantitative data shows that the sequential learning pattern that was suggested by the system was the most preferred way of learning. The learning pattern was indicated by the learners' use of the *next suggested page* button to access the information and navigate through the environment. This button is based on the user model and provides a simple annotated links for users to access the next recommended page or node. This page or node is suggested and available after achieving a specified rate of learning on the previous pages or nodes. The learning rate on a node represents users' success in solving a set of prescribed exercises or tests about the content in the node and/or previous nodes. The data also show that most users visited every page or node. The use of *outline frame* that allows users to move within the pages of their own volition was less common.

Second, the data indicate that most students learnt most of the basics of the authoring tool use from the system for the learning environment in a relatively short time. This suggests that the prototype learning environment was effective in providing learning experiences in basic knowledge of the use of the authoring tool. The use of the simplest user model-base annotation link seems to be the preferred mode of navigation. This supports previous findings, which showed that adaptive link annotation is valued by students who accept and follow the suggestion [2] as students who agreed with the 'cognitive model' of the knowledge that the author placed on the content were likely to follow such a navigation path. Thus, learners take advantage of the fact that the content has been examined and structured for them.

The choice of navigation path may also be due to the learner background, previous experiences, and existing knowledge. The suggested navigation path may provide the optimum learning support for users with limited relevant experiences and knowledge. It was reported that novice learners profited from being guided directly by the system when using the similar path of navigation. Without such guidance, they had to navigate through course materials on their own, which may lead to disorientation and cognitive load problems. Adaptive guidance by the environment appears to be especially helpful for novices.

The result of Wilcoxon Signed-ranked test on the data indicates that there was significant difference in students' test scores between pretest and posttest stages. This suggests that the use of the system may have improved students' conceptual and procedural knowledge about the basic use of the authoring tool but again it needs to be acknowledged that other instructional systems may achieve similar results. The analysis of the distribution of data also shows that score improvements were, with one exception, the maximum possible. Further, it also indicates that large score improvements were identified for the students with lower pretest scores. These suggest that the use of an adaptive learning environment benefited most learners. These findings are consistent with the previous study, which also showed that students acquired more declarative knowledge by using adaptive learning environments [14]. These kinds of environments have been effective for learning declarative and procedural knowledge [13]. It also supports a study,

which showed that adaptive learning environments have been beneficial to students who tend to accept the navigation advice, particularly when they are unfamiliar with a complex interface [2]. In this study students who gained the most were often those with low levels of relevant knowledge of subject content or other related background or experiences.

The Use of Adaptive Annotation Technology

The next question addresses is whether the technique, adaptive annotation technology, useful. The data were drawn from the questionnaire and interviews. The data analysis indicates that the adaptive annotation link technology or technique, which is implemented in the prototype to provide adaptive navigation support, was considered helpful for acquiring conceptual and procedural knowledge about using the authoring tool. The learners here suggested that this was due to availability of textual and visual cues. These cues enabled them to know their learning status (the proportion of material learned) and the relative position in the hyperspace. There was also an indication that it was helpful since the implementation of the technology enabled them to proceed with learning at their own pace.

The quantitative data were then triangulated with qualitative data from interviews with analysis of the interviews indicating a similar result; that is, the adaptive annotation links helped users to understand topics covered in the learning environment, particularly to acquire conceptual and procedural knowledge about using the authoring tool. Similar pattern of response were also found on why adaptive annotation links were helpful for the purpose.

To summarize, this study shows that then use of adaptive annotation technology for the adaptation technique in the web-based learning environment was helpful for supporting learning *HyperStudio* use, particularly for acquiring conceptual and procedural knowledge about the basics of using the authoring tool. It also indicates that this was due in large part to the fact that the technology of the environment provides a clear and well-structured navigation system which provides the users both with textual and visual cues about the relative position of the user within the space and/or to proceed with their learning at their own volition depending on their needs and backgrounds.

This finding confirms previous findings on the use of the technique in educational hypermedia. It was shown that adaptive annotation links in educational hypermedia could reduce disorientation and make learning more goal-oriented [3]. Further, others also claimed that the adaptive navigation support features are useful in improving comprehension for students who deal with complex interfaces for the first time [2].

IV. CONCLUSIONS

The findings suggest that the use of adaptive web-based learning environments significantly improves learning. In particular, the participants indicated that the use of the learning environment here significantly improved learners' conceptual and procedural knowledge about the basics of using *HyperStudio*. As stated previously, this finding supports previous findings that adaptive learning environments are effective in supporting learning in acquiring these types of knowledge [13, 14]. It is also indicated here that learners placed a high educational value on this environment in terms of its user consideration, content, instructional value, visual design, and ease of use.

Adaptive navigation support is a method of guiding learners to find learning paths or to provide them with the most efficient way of learning or accessing information in hyperspace according to their needs, knowledge and preferences. The effectiveness of the implementation of this method in educational hypermedia would be greater if the hyperspace is relatively large. Prescriptive or tutorial form in educational hypermedia might be an appropriate instructional strategy to support learners acquiring conceptual and procedural knowledge.

Adaptive annotation technology is a feature of adaptive navigation support. In this study the use of the technology was seen as being helpful for learning. This results support previous findings on the use of the technique [2, 3, 19]. It is due to that the technique provides learners with textual and visual cues about their learning status and relative position in the hyperspace. The use of the technique here appeared to reduce cognitive overload and/or disorientation problems that the learners might have encountered, but Murray et al. [10] suggest that the use can also help hypermedia users with problems associated with discontinuous flow and content readiness. Therefore, it can be concluded that adaptivity, or implementation of adaptive navigation technique in particular, in learning environments, may enhance the learning process.

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