Usage patterns: Highlighting differences in problem solvers

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Abstract

This paper reports a study designed to determine how learners use and interact with Child Growth & Development in the first 12 months of life, *a highly interactive educational technology program. The design of the program was informed by principles of problem based learning and the key learning activity for students is the resolution of problems relating to a family and their child. We describe how an electronic record of users' movements and activities within the program was captured using an embedded audit trail system. Analysis of this data revealed two usage patterns described as either specific or general depending on the order in which resources were accessed, and the way they were accessed. Specific learners used a quick, targeted approach to find resources to assist them with their problem solving activities, while general learners used a systematic approach, taking up to 50% more time to browse through resources. We were also able to identify a correlation between the usage patterns and learners' understanding of the problem. We suggest that the different usage patterns reflect variability in the process of searching for or generating possible solutions to the problem. This finding has implications for the future design of educational technologies that support the learning of problem solving.*

Keywords

problem solving processes, educational technologies, audit trails, usage patterns

Introduction

For this year's ascilite conference, participants have been asked to explore ways that will ensure the continuing evolution of the field of educational technology. As an emerging field, educational technologies were often seen as *potential* educational resources and efforts were concentrated on finding out whether they would improve student understanding. Moreover, many evaluations aimed to determine the effectiveness of educational technologies over traditional methods of teaching and learning, a difficult task considering the number of variables involved. In the current evolutionary climate of blended learning environments, there is general acceptance that educational technologies stand along side other teaching and learning approaches (e.g. lectures, laboratory sessions, small group tutorials, self-directed study) as valuable educational tools.

During the growth phase of the field, many products were developed (and continue to be developed) to address practical educational problems. These products were often informed by current educational philosophies and theories such as constructivism, problem-based learning, situated cognition, distributed cognition, generative learning, and cognitive flexibility. Because of their theoretical based design, we now have the opportunity to use these innovative products as research vehicles to investigate how students learn with educational technology. By assessing how students use these programs it may also be possible to further our understanding of learning processes such as problem solving, collaboration and reasoning. The focus of this paper is particularly on students' problem solving skills.

Problem solving is regarded as among the most valued generic skills that young people need for life-long learning (Oliver & Towers, 2000). Jonassen (2000) argued that problem solving is the most important cognitive activity in every day and professional contexts. Yet despite its importance, the teaching of problem solving in formal education has received little attention. Furthermore, little advice is available on the design of educational materials (including educational technologies) to teach problem solving, apart from general recommendations to use authentic cases, simulations, modelling, coaching and scaffolding (Jonassen, 1997). Jonassen (2000) suggests that this is because the problem solving process itself is poorly understood.

In general terms, solving a problem can be seen as transforming a given situation into a desired situation or goal (Hayes, 1989). However, our current understanding of problem solving is based on symbolic processes rather than neural events. These processes are outlined in Gick's (1986) model of problem solving processes, which describe the learner constructing a representation of the problem (problem space), searching for or generating possible solutions to the problem, and implementing and monitoring solutions. Although Gick's model incorporated several previously published models (Newell & Simon, 1972; Bransford & Stein, 1984) it is regarded as a simplified version of events, and is limited by the fact that it doesn't take into account differences in problem type (Jonassen, 2000). With regard to the initial process of constructing a problem representation (Jonassen, 1997) adds that:

> This process involves mapping the problem statement onto prior knowledge and constructing a personal interpretation of the problem. In the problem space, the solver attempts to decompose or isolate attributes of the problem, while identifying an appropriate solution state (p. 70).

More recently, efforts have been made to describe the variability of problems (structuredness, complexity), problem representations and individual problem solvers, with an end goal of producing task-specific models to support the learning of problem solving (Jonassen, 2000). Thus a number of theoretical models of problem solving have been proposed, updated and modified over the years. Moreover, it is now thought that there is no one type of problem nor is there one type of problem solver (Jonassen, 2000). A useful progression in this area of research is to investigate how students actually solve problems.

Problem Based Learning (PBL) is a popular teaching and learning strategy that utilises authentic problems as a context for small groups of students to learn problem-solving skills and to acquire knowledge (Albanese & Mitchell, 1993; Norman & Schmidt, 1992). In PBL medical curricula, problems are usually organised according to themes rather than being discipline-based, which allows the learning of basic sciences to be integrated with the acquisition of clinical knowledge (Norman & Schmidt, 1992). Variations of PBL are practiced at different institutions, however, generally students attempt to solve the patient problems by analysing available information, formulating hypotheses and then testing the hypotheses in light of additional information they encounter, thereby arriving at a diagnosis and management of the case. Students may also explicitly analyse the processes undertaken to solve the problem (Barrows, 1986). Barrows (1986) proposed that through the repeated practice of the problem solving process (with facilitator support), students acquire problem-solving skills in a clinical context. As mentioned above, educational technology programs that adopt a PBL design and use real-life problems as the stimulus for problem-solving activities provide a useful vehicle to investigate the problem solving skills of students.

This paper proposes that question-led research using purpose built products will guide the way forward in the field of educational technology. Indicators of how a program is used by students often arise out of evaluation studies, which can be used as the basis of a research agenda. Research outcomes may provide some answers, but often raise further questions, from which future investigations can be planned. At this evolutionary stage, it is essential to move beyond the question of whether a particular educational technology works well, towards determining how the educational technology works. For example, how do students use and interact with the technology to gain understanding of a skill or topic. To illustrate this approach, the authors describe an investigation that determined usage patterns of learners solving problems with an educational technology program, used by medical students at the University of Melbourne.

A question for research

In an earlier paper (Elliott et al., 2003), the results of a pilot focus group evaluation of the educational technology program *Child Growth & Development in the first 12 months of life* were described. In short it was found that medical students enrolled in a PBL curriculum rated the program more favourably than a student enrolled in a traditional medicine course. The former group were more comfortable with, and more expert at the self-directed, exploratory nature of the program, and were more aware of the learning processes (e.g. problem solving processes) that they were involved in whilst using the program (Elliott et al., 2003).

While it was difficult to draw any firm conclusions from the study because of the small sample size (n=3), it did raise a number of intriguing questions. For example, were some students more apt at using the problem solving design of the program than others, or did this result reflect the exposure to, and training in problem solving methodology that students in a PBL curriculum receive? Since it has been argued that programs such as *Child Growth & Development* that are designed according to PBL principles can be integrated into PBL environments and used as tools to reinforce the learning of processes such as problem solving and clinical reasoning (Harris, Keppell, & Elliott, 2002), it is important that as educators and designers we understand how students use these programs and if usage patterns actually match with design expectations. Furthermore, when considering potential learning benefits of programs, it is critical to identify common usage patterns because each may lead to different learning outcomes.

The study described in this paper goes some way towards providing answers to the questions raised by the initial evaluation feedback. It was conducted primarily to determine how students use and interact with the *Child Growth & Development* program, and relied upon both internal and external measures. An electronic record of users' movements and activities within the program was captured using an embedded audit trail system (Judd & Kennedy, 2001). Although there is ongoing debate about the utility of audit trail analysis (Reeves & Hedberg, 2003) Kennedy and Judd (2004) recently employed a range of analytical techniques to demonstrate consistent and meaningful patterns of usage of a highly interactive educational technology environment. In the current study, interviews and questionnaires were used to supplement the audit trail analysis and provide more meaningful interpretation.

The Child Growth & Development program

Child Growth & Development was developed to facilitate the teaching and learning of child growth and development to medical students studying paediatrics. It is structured around the home life of a family and their newborn son, with students "visiting" the family when the infant is two weeks, six weeks, three months, six months, nine months and 12 months old. At each visit, age-related concerns are raised about the infant's growth or development, which students work through before outlining the most appropriate advice for the family. Child health and family issues such as feeding, crying, immunisation, Sudden Infant Death Syndrome (SIDS), stranger anxiety and post-natal depression are introduced to students during relevant visits. The program also offers an opportunity for students to observe the progressive growth and development of the same child over time, through the use of extensive video footage of him performing age-related tasks and behaviours.

The theoretical design of the program was informed by the principles of PBL and employed a commonly used PBL learning sequence composed of: problem presentation, problem analysis, formulation of hypothesis to explain problem, identification of individual learning objectives, further inquiry and data gathering, opportunity to reflect and refine hypothesis, decision making or application of newly gained knowledge to original problem, and prediction of future situations. Problems were supplemented by a rich variety of resources, which students could access at any point during the problem solving process. The design of problem solving activities in *Child Growth & Development* is shown below in Figure 1.

As mentioned previously, the key learning activity of this program is to solve problems related to a family and their newborn baby. In the first visit, for example, the mother is anxious about her baby's unsettled behaviour. Students are required to determine whether this is normal behaviour for a two-week old baby or whether there is an underlying cause such as inadequate breastfeeding, maternal health problems, or a medical condition affecting the baby. The problem is divided into seven tasks, which guide students through the problem solving process (see Table 1).

To help students complete tasks, two sets of additional resources were provided. The first set consisted of material relating to infants (newborn to six week old) and contained additional readings, graphical data, simple drag and drop exercises, multiple choice questions, images, videos and links to web sites. Materials were grouped under the headings: Development, Growth, Health and Family, and were accessed via drop down menus. The second set of resources - a video library containing footage of the infant from newborn through to 12 months - could be accessed via a pull out navigation bar.

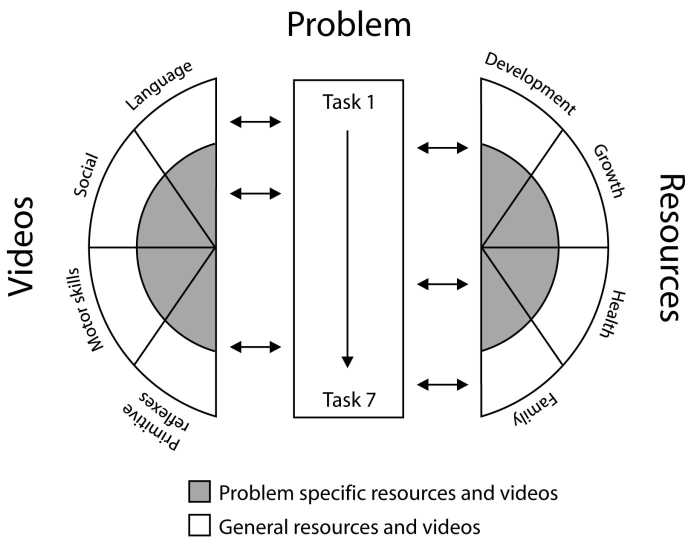

Figure 1: Design of problem solving activities in the Child Growth & Development *program*

In both sets of resources, some items related specifically to the problem at hand (referred to as *problem specific* resources), while others were more general. The program contained five *problem specific* resources (shown below in order of importance):

i. Health > Feeding
ii. Development > Behavioural states
iii. Growth > Measuring
iv. Development > Motor Development
v. Development > Communication

It also contained six *problem specific* videos (shown below in order of importance):

i. Breastfeeding (attaching)
ii. Breastfeeding (rhythmic sucking)
iii. Breastfeeding (rhythmic sucking 2)
iv. Crying
v. Fussing
vi. Rooting reflex

In addition, there were nine general resources and eleven general videos.

Table 1: Problem-solving process used for the first visit in the Child Growth & Development *program*

Task	**Instructions**	**Comments**
1. Clarify problem	Play the video and listen to Louise's [the mother's] comments. Enter any parental concerns you identify into the notebook and then submit.	Key learning activity: video clarifies problem
Feedback 1	Expert feedback	Appears when learners' response is submitted
2. Formulate hypothesis	What possible hypotheses might explain the situation between Jack [the baby] and Louise? (e.g. what factors could be causing, contributing to, or influencing the parental concerns?) Enter your hypothesis/es into the notebook and then submit.	Before completing this task, learners are encouraged to investigate additional resources in the Resources or Video library.
Feedback 2	Expert feedback	
3. Identify learning needs /Research	What additional questions would you like to ask Louise? Enter these in point form into the notebook and then submit.	
Feedback 3	Expert feedback	
4. Identify learning needs /Research	What information do you require from a physical examination? Enter these in point form into the notebook and then submit.	
Feedback 4	Expert feedback	
5. Research	Plot Jack's growth on his centile chart.	
Feedback 5	Expert feedback	
6. Hypothesis testing	Use the additional information you have gathered to formulate your understanding of the problem. Enter your formulation into the notebook and then submit.	
Feedback 6	Expert feedback	
7. Solution	What advice would you give Louise regarding her concerns about two week old Jack? Outline your advice in the notebook and then submit.	Here learners are prompted to revisit resources if necessary.
Feedback 7	Expert feedback	

Methods

Study sample

The sample consisted of six participants who were casual staff employed in the Faculty IT unit (e.g. medical students in the latter years of their course who supervise the computer laboratory and part-time research assistants). Each participant was briefly introduced to the program and then allowed to work through the program unsupervised and at their own pace. An audit trail of each participant's activities was saved when they exited the program. After completing the program, participants were given a questionnaire to fill out, and were briefly interviewed about their educational background (including familiarity with PBL), their impression of the program and other relevant issues.

Measures of learners' activities

Audit trail

A customised version of *Child Growth & Development* was developed for this study, consisting of one home visit (when the infant is two weeks old). While the general functionality of the customised and standard version were very similar, navigational controls in the former were modified so as to restrict access by users to those sections of the program directly relevant to the study. An audit trail system (Judd & Kennedy, 2001) was employed to capture key behavioural responses and activities of learners as they worked through the program. This system, which employs both event-based (related to a physical action — e.g. mouse click, menu selection) and object-based (related to a physical or conceptual object — e.g. screen, complex task) data capture, was embedded in the program and configured to create comprehensive records of which components of the program were accessed, in what order, and for how long, as well as of users' textual responses to key tasks. Captured records were stored in a convenient and readable xml format for later analysis. Audit trails were coded blind (the identity of the users was unknown to the coder).

Questionnaire

To verify any usage patterns emerging from the audit trial data against external measures, participants were asked to respond to the following open-ended questions directly after completing the program:

i. What was the problem that you had to solve in the *Child Growth & Development* program?
ii. Describe how you went about solving the problem (try and recreate the steps you took to solve it).
iii. Did you experience any difficulties solving this problem?

Data analysis and interpretation

Audit trail

The six sets of audit trail data were analysed to determine general usage patterns. This was achieved by comparing each data set to a model sequence based on the underlying educational design of the problem. The model recognised key learning activities in the problem solving process, along with problem-specific resources and videos that learners would be expected to access in order to successfully resolve the problem. By way of example, viewing the video at Task 1 was considered a key learning activity, since this was necessary to define the problem. Also, Task 2 was of particular interest because it represented a "jump off" point from the problem into the problem solving space where further investigations could be carried out. This was a critical point to determine (i) what order the resources were investigated in (whether learners were selective/targeted or sequential/systematic in their use of resources), (ii) the type of resources selected (problem specific or general), (iii) the number of problem specific resources visited and (iv) the time spent on problem specific resources. Throughout the problem solving process, the frequency of visits to each task and expert feedback, along with the time spent on these activities was also recorded. This allowed any "review loops" used by learners to be identified. Review loops were defined as when learners moved between a particular task and the problem solving space, consecutively, at least three consecutive times. Complete learner profiles constructed from audit trial data, are shown in Table 2.

The usage patterns of learners were classified as either specific or general depending on the order in which resources were accessed from Task 2 (the "jump off" point), and the way they were accessed. Learners A, B and C did not access resources in the order they appeared in the program menus. Instead, they targeted problem specific resources. Learner A for example, went straight to the most critical problem specific resource (Health > Feeding), and returned to it repeatedly (six times) throughout the problem solving process.

Learner C targeted the two most important problem specific resources first (Health > Feeding followed by Development > Behavioural states), and then viewed all six problem specific videos. Learner B targeted the second most important problem specific resource Development > Behavioural states, followed shortly by the most important, Health > Feeding.

Conversely, learners D, E and F displayed a general usage pattern, systematically going through all 14 resources in a linear fashion that replicated the order they appeared in the program menus. No distinctions were made between problem specific or general resources. Both learners D and F indiscriminately (in no particular order) visited up to seven resources prior to reaching Task 2, so would have been aware of the problem specific resources, but perhaps did not realise their significance and chose to go through all resources in turn, once they reached Task 2.

Table 2: Learner profiles constructed from audit trial data

	Learner					
	A	**B**	**C**	**D**	**E**	**F**
Usage pattern	**Specific**	**Specific**	**Specific**	**General**	**General**	**General**
Problem video (task 1) (No. of times played)	2	3	1	9	3	6
Problem specific resources visited (No. out of 5)	1	4	5	5	5	5
Total time spent on problem specific resources (secs)	63.0	279.2	157.8	530.99	1010.9	1227.3
Problem specific videos played (No. out of 6)	0	1	6	0	0	0
Visited video library	Yes	Yes	Yes	No	No	No
Time spent on tasks (secs)						
Mean	76.6	155.3	131.1	184.6	64.7	190.3
SD	46.9	118.3	38.9	123.2	40.7	218.6
Frequency of visits to tasks						
Mean	2.3	1.4	2.3	2.4	1.1	4.0
SD	1.4	0.8	1.0	0.8	0.4	1.9
Number of task review loops	2	1	4	4	0	6
Time spent on feedback (secs)						
Mean	21.0	11.4	83.6	99.9	43.9	22.3
SD	17.0	8.9	171.2	166.0	59.7	28.1
Frequency of visits to expert feedback						
Mean	1.4	1.0	1.6	2.3	1.0	2.7
SD	0.8	0.0	0.8	1.3	0.0	1.0
Number of feedback review loops	1	0	1	4	0	4

Interestingly, learners who displayed a general usage pattern spent significantly more time (at least 50% more) on the problem specific resources, than their counterparts who used a specific pattern (see Table 2). This trend is more consistent with general browsing through the resources, in contrast to the quick, efficient, targeted behaviour of the Specific Users.

In regard to the frequency of visits to each task, the frequency of visits to feedback and the time spent on these activities, no differences could be determined between General and Specific Users (see Table 2). Each learner spent different amounts of time on different tasks, different feedback and completed review loops at different points of the problem solving process. This behaviour most likely reflects the esoteric nature of learning; each learner bringing to the program their own individual knowledge, experiences, interests and motivation. Not surprisingly, because of its' pivotal role in the problem solving process, Task 2 was the most frequently visited task by both types of learners.

External measures

Questionnaire responses of participants were coded using the following schema. Responses to Question 1 ("What was the problem that you had to solve in the *Child Growth & Development* program?") were given a score out of 10 according to whether the problem was stated specifically (5.0) or in general terms (2.5), and whether the following criteria were included; problem indicators were stated (1.0), other causes were stated (1.0 each), implications were stated (1.0 each), outcome was stated (0.5), associated factors were stated (0.5). Values attributed to each criterion are shown in brackets.

Responses to Question 2 ("Describe how you went about solving the problem - try and recreate the steps you took to solve it") were compared to an eight-step model problem solving sequence where Step 1 = Identification/Clarification of problem, Step 2 = Hypothesis formulation (possible solutions), Step 3 = Identification of learning needs, Step 4 = Enquiry driven (specific) search of resources, Step 5 = Hypothesis testing (matching new knowledge against learning needs), Step 6 = Review (general search of resources), Step 7 = Hypothesis revision, Step 8 = Solution.

Scores obtained for the problem analysis (Q 1) were used to judge learners' understanding of the problem after completing the program. Accordingly, Specific Users A, B, and C, appeared to have a good grasp of the problem and its associated issues (scoring between 6 and 7.5 out of 10, see Table 3). However, General Users D, E and F appeared to have a poorer understanding of the problem, scoring between 0.5 and 3.0 out of 10).

Table 3: Learner profiles constructed from questionnaire responses

	Learner					
	A	**B**	**C**	**D**	**E**	**F**
Problem analysis (Score out of 10)	7.5	7.5	6.0	0.5	2.5	3.0
Problem solving process (learners' own description)	General	Specific	Specific	General	Specific	General
Sequence of problem solving events (learners' own description)	1, 3, 6, 4	1, 2, 3, 4, 5, 8	1, 2, 4, 7	1, 6, 5	1, 2, 4, 5, 6*	4, 6, 1
Background	No PBL Female	PBL (Medicine) Female	PBL (Medicine) Male	PBL (Medicine) Male	No PBL Female	No PBL Male

* Learner E described this event, but noted that they didn't actually do it.

Adding weight to this finding were the free text responses entered by learners at tasks 1, 2, 3, and 4, and captured by the audit trail. Free text entries are indicative of what learners are thinking at particular points in the program, and by comparing them to an "expert response" it was possible to get a good picture of learners' progression through the problem. Specific Users scored higher on these problem-solving tasks (A=40%; B=42%; C=64%) than General Users (D=34%, E=18%; F=20%).

The interesting point here is that these scores can be directly linked to the usage patterns identified in the audit trial data. Learners A, B and C who showed a stronger understanding of the problem (Q 1) were also those who used a specific pattern of use, targeting problem specific resources in the initial stages of the problem solving process. The other group (D, E and F) with a less comprehensive understanding all followed a general pattern of use and searched through the resources in a linear fashion.

When learners described the steps they used to solve the problem, individuals from both specific and general users made distinctions between problem specific and general resources:

- "… used the resource pages that were relevant to the problem" (Specific User C)
- "… read through all the resources to understand all the information available to me" (Specific User A)
- "The information resources visited first were the ones I thought might be most relevant" (General User D)

However, in two cases (A and E) the descriptions of how the problem was solved differed significantly to what was actually done in the program (as recorded by the audit trail). For example, Specific User A described doing a general search for resources when in fact it was highly specific in comparison to other participants, and General user E described an enquiry-driven search for resources when the audit trail data showed a systematic search through all resources. Since neither of these participants had a background in

PBL, this discrepancy may be explained by subject's imprecise use of problem solving terminology to describe their actions.

Regardless of their backgrounds (medicine, non-medicine, PBL, non-PBL), all participants including those with a greater understanding of the problem noted some degree of difficulty solving the problem. In the Specific Users group, subject A wrote it was "Difficult to assimilate all the information", subject B commented that because it wasn't a real-life activity it was not possible to use environmental clues to guide their problem resolution, and subject C noted "… some difficulty, [having] no training in this field". Similar comments were made by the group of General Users with less understanding of the problem, "Unsure of what was expected" (subject D), "Some difficulties — no training in treating patients, little knowledge of topic" (subject E) and "Lack of medical knowledge definitely a problem" (subject F).

In the study sample, participants' backgrounds did not seem to be linked to the different usage patterns. In the case of the Specific Users, learner A was not a medicine student and had no exposure to or training in PBL, while both B and C were medical students and had taken part in the PBL curriculum. In fact, Learner C remarked that the structure of the program was similar to the medical problems encountered weekly in PBL sessions. As for the General Users, only learner D had any medical training (medical student) or PBL experience.

Conclusion and future directions

The study reported here has identified two different patterns of use for the *Child Growth & Development* program. Specific learners use a quick, targeted approach to find resources to assist them with their problem solving activities. They target problem specific resources early on in their search for information. In contrast, General learners use a systematic approach to searching, taking up to 50% more time to browse through resources. They do not appear to make initial judgements about which resources will be more helpful, preferring to go through all the resources in the order they appear in the program.

We have also highlighted a correlation between the usage patterns and learners' understanding of the problem. Specific learners were able to describe the problem in greater detail and completed problem-solving tasks more competently. In comparison, general learners had a poorer understanding of the problem and did not score as highly on problem solving tasks. In fact, learners' understanding of the problem seemed to be more important in determining the usage pattern than other factors such as a medical background, experience with PBL or gender.

The study has, therefore, shown that given a single problem-based scenario, learners approach the solving of this problem in a number of ways. This supports Jonassen's (2000) contention that internal factors cause variation between individual problem solvers. While the variability of problems, problem representations and individual problem solvers has been highlighted in the literature (Jonassen, 2000), the results obtained here suggest that the process of searching for or generating possible solutions to the problem may also vary. This has implications for the design of educational technologies that support the learning of problem solving, and suggest that as in the *Child Growth & Development* program, learners need to be provided with a high degree of flexibility as they search through the resources for possible solutions to the problem. If designs are too prescriptive about how resources are accessed, some learners may be disadvantaged.

This study also demonstrates how educational technology programs can be used to investigate student's problem solving process. We are interested in using a similar mixed method approach with a large sample of learners, to determine if the same usage patterns emerge and if significant differences can be found between different types of problem solvers. More empirical research in this area will further our understanding of student's learning processes generally. They may also offer suggestions to educators and designers as to how to design programs to better facilitate adaptive learning processes.

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