Question Asking During Learning with a Point and Query Interface

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Abstract

Educational software would benefit from question asking facilities that are theoretically grounded in psychology, education, and artificial intelligence. Our previous research has investigated the psychological mechanisms of question asking and has developed a computationally tractable model of human question answering. We have recently developed a Point and Query (P&Q) human-computer interface based on this research. With the P&Q software, the student asks a question by simply pointing to a word or picture element and then to a question chosen from a menu of "good" questions associated with the element. This study examined students' question asking over time, using the P&Q software, while learning about woodwind instruments. While learning, the students were expected to solve tasks that required either deep-level causal knowledge or superficial knowledge. The frequency of questions asked with the P&Q interface was approximately 800 times the number of questions asked per student per hour in a classroom. The learning goals directly affected the ordering of questions over time. For example, students did not ask deep-level causal questions unless that knowledge was necessary to achieve the learning goal.

Introduction

Question asking and answering play a crucial role in some learning processes (Collins, 1988; Miyaki & Norman, 1979; Schank, 1986). The number and quality of student questions depends on the student initiative that is required in the learning environment. In a classroom environment, learning is not generally under the control of the student, so student questioning approaches zero (Dillon, 1988; Kerry, 1987). A tutoring environment requires the student to take a more active role in the learning process, and this is reflected in substantially more questions asked by the student. For example, approximately 0.2 questions are asked by a student per hour in a classroom whereas 20 questions per hour are asked in a tutoring session (Person, 1990).

Graesser, Person, and Huber (1992) identified four classes of cognitive mechanisms that underlie human question asking: (1) correction of knowledge deficits, (2) monitoring common ground, (3) social coordination of action, and (4) control of conversation and attention. The number of student questions in the knowledge deficit category is a good measure of student initiative; that is, students who ask a lot of questions in this category are active, inquisitive learners capable of identifying and repairing their own knowledge deficits (Brown, 1988; Brown et al., 1983; Palinscar & Brown, 1984; Pressley et al., 1987). As the learning environment shifts the initiative from teacher to student, one would expect that the number of knowledge deficit questions would increase. This is evident in the questions asked by students during tutoring, where 30% of student questions addressed knowledge deficits (Person, 1990).

As the student takes a more active role in the learning process, the environment must be capable of supporting a large, diverse number of student questions. Therefore, there is a need for question asking facilities in educational software. Unfortunately, most of the existing human-computer interfaces (Tennant, 1987; Williams, 1984; Zloof, 1975) have not had ideal question asking facilities. Each of these interfaces suffers from one or more of the following six problems:

(1) **Questioning time.** With current questioning interfaces, it takes the student a long time to ask a question, often several minutes.

(2) **Ease of use.** Questioning interfaces are often quite complex and require hours for the users to learn how to ask a question.

(3) **Question interpretation.** The computer will sometimes misinterpret the query posed by the student, and respond with the wrong information.

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(4) **Question answering.** Software designed to answer questions should be grounded in a psychological theory of human question answering.

(5) **System ambiguity.** It is not clear to the user what questions the system can answer.

(6) **System focus.** The knowledge base is not organized around questions and answers to questions.

We have developed a Point and Query (P&Q) interface (Graesser, Langston, & Lang, 1992) that attempts to correct all these problems. First, it is very easy for the student to ask a question with the P&Q interface. With two clicks of a mouse, the student can easily ask a question and receive an answer within two seconds. Second, it is very easy for the student to learn to use the P&Q interface. It takes approximately five minutes to learn how to use the system, if the student is familiar with the use of a computer mouse. Those students unfamiliar with the mouse require an extra few minutes. Third, the P&Q system can quickly and correctly answer a question according to a psychological model of human question answering called QUEST (Graesser & Franklin, 1990). The P&Q system and Schank's ASK TOM system (Schank et al., 1991) are the only systems based on an empirically tested psychological theory of question answering (although ASK TOM has not yet been rigorously tested using human subjects). Fourth, the student has direct feedback on what questions the P&Q system can answer at any point in time because a list of relevant questions is displayed in a menu on the screen. This allows the student to learn what questions are good questions. The menu of relevant questions is contingent on the type of knowledge structure the student is curious about, e.g., goal/plan hierarchy, causal network, taxonomic hierarchy, or spatial information. Fifth, the knowledge base in the P&Q interface is organized around questions and answers to questions.

The QUEST model (Graesser & Franklin, 1990) greatly influenced those questions and answers in the interface. The QUEST model specifies what questions are appropriate for the domain through an analysis of the knowledge structures in the domain to be learned. QUEST specifies which information units from an information source are legal answers to a particular question. Whenever an answer to a question provided little or no new information, the question was not included in the menu of questions.

The P&Q system in this study contained knowledge about woodwind instruments. This domain was chosen because it is knowledge-rich in each of the following types of knowledge, or "viewpoints" (Graesser & Clark, 1985; Souther et al., 1989; Stevens, Collins, & Goldin, 1982):

(1) **Taxonomic knowledge**, which includes taxonomic hierarchies and concept definitions.

(2) **Spatial composition**, incorporating the spatial layout of objects, parts, and features.

(3) **Sensory information**, including visual, auditory, kinesthetic, and other sensory modalities.

(4) **Procedural knowledge**, embodying the actions, plans, and goal structures of agents.

(5) **Causal knowledge**, which captures causal networks and states in technological, biological, and physical systems.

These viewpoints are closely interrelated, with mutual constraints and associative mappings between each of the different types of knowledge.

There has been very little empirical research on patterns of exploring knowledge by asking questions, particularly in the context of knowledge-rich domains. This lack of research prompted the present study. We examined the patterns of student questions while they sampled deep causal knowledge versus comparatively superficial knowledge (i.e., taxonomic, sensory, spatial, and procedural knowledge). We manipulated the goals of the student during the learning process, such that they were to focus either on deep causal or superficial levels of knowledge. The purpose of this study was not to evaluate our software as it affects learning. Instead, we were interested in documenting the subjects' course of exploring knowledge over time, how goals affect this process, and how the subjects' questioning rate compares to other contexts (i.e., classrooms and tutoring).

Methods

Goals of student

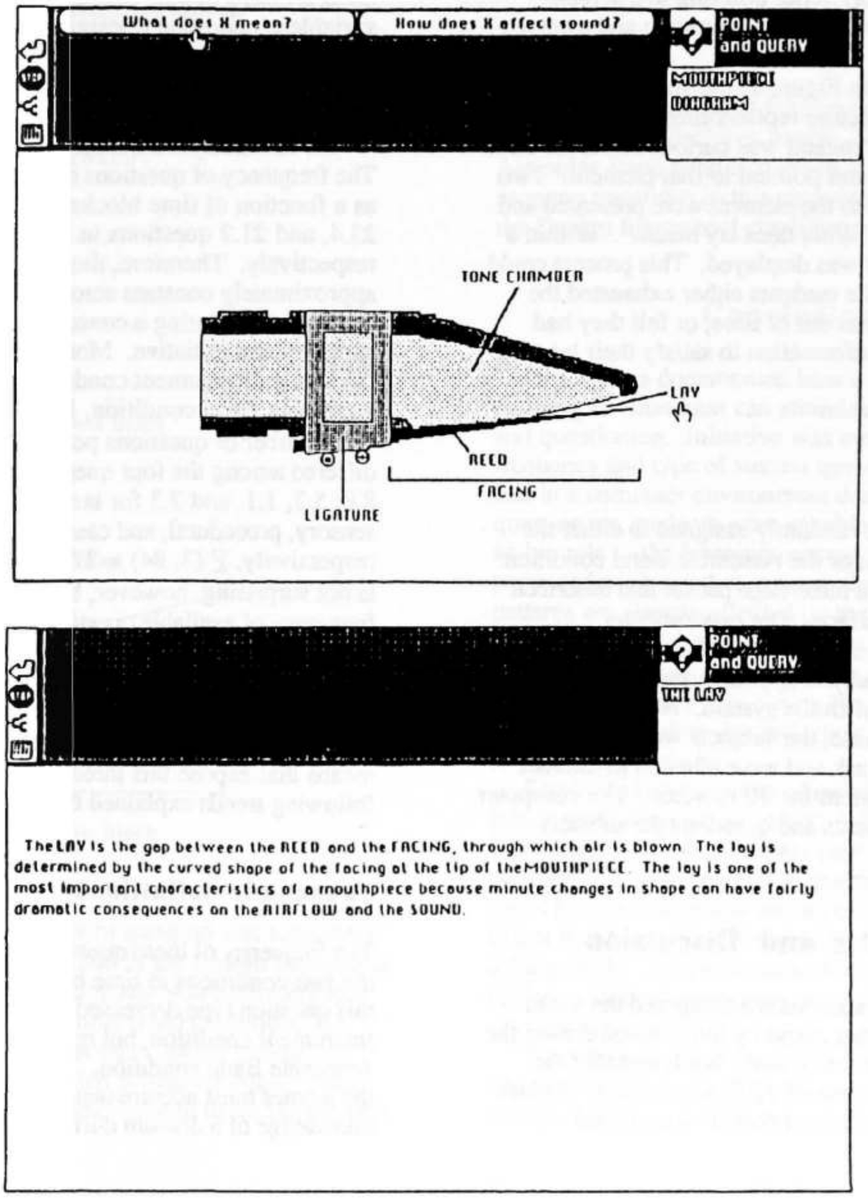
Subjects were 32 undergraduate students at Memphis State University. Half of the subjects were expected to acquire deep causal knowledge of woodwind instruments (Design Instrument condition), whereas the other half could rely on superficial knowledge (Assemble Band condition). In the Design Instrument condition, the subjects were told to design a new woodwind instrument that had a low pitch and that was pure in tone. The solution to this task required the student to have a deep causal knowledge of woodwind instruments; the student would have to understand causal relationships between the physical features of a musical instrument and the properties of its sound. Subjects in the Assemble Band condition were instructed to assemble a band with six types of woodwind instruments to play at a New Year's Eve party. The solution to this task does not require a deep causal understanding of woodwind instruments; the task could be completed using only superficial knowledge about what the instruments look like, what they sound like, and what their names are.

Computer software

The computer software consisted of a knowledge base about woodwind instruments in a hypertext environment with a P&Q interface. The computer was a Macintosh microcomputer. The knowledge base consisted of approximately 500 "cards" (screen displays) in the hypertext system. The cards included two "seed" cards: a taxonomy of woodwind instruments and a diagram of air flow through each component of a prototypical instrument. The rest of the cards were answers to possible questions that could be asked by the student.

There were 10 generic question categories that a student could choose from when the student selected an element of information to query. The types of knowledge these questions addressed were: taxonomic hierarchy ('What does X mean?', 'What are the properties of X?', 'What are the types of X?'), definitions ('What does X mean?'), sensory information ('What does X look like?', 'What does X sound like?'), spatial composition ('What does X look like?'), procedural knowledge ('How does a

Figure 1. An example question and answer interaction using the Point and Query Interface.



person use/play X?') and causal knowledge ('How does X affect sound?', 'How can a person create X?', 'What causes X?', 'What are the consequences of X?'). These 10 question categories address most relevant questions that could be asked at any given time about particular elements in the knowledge base. Categories that contain instances of the same question type are collapsed and considered one category (e.g., Taxonomic-Definitional, Sensory-Spatial). When the student was presented with a screen of information, there were particular elements that were highlighted. The students pointed to one of the elements they were curious about. A particular subset of the 10 question categories was presented according to (1) the QUEST psychological theory of human question answering (Graesser & Franklin, 1990), (2) the knowledge structures associated with the queried element, (3) the good questions associated with the type of knowledge structure, and (4) whether or not a question has an informative answer. After pointing to a screen element, the student selected a question and received the answer.

For example, in Figure 1, the student was presented with a picture representing a single reed mouthpiece. The student was curious about the LAY of the instrument and pointed to that element. Two questions relevant to the element were presented and the student asked 'What does lay mean?'. Within a second the answer was displayed. This process could then repeat until the students either exhausted the knowledge base, ran out of time, or felt they had acquired enough information to satisfy their learning goals.

Procedure

The subjects were randomly assigned to either the Design Instrument or the Assemble Band condition. The subjects read a three-page packet that described the use of the interface. The experimenter demonstrated the use of the interface to the subject, and allowed the subject approximately one minute to become familiar with the system. At the end of the familiarization phase, the subjects were given their problem solving task and were allowed to interact with the P&Q system for 30 minutes. The computer recorded the elements and questions the subjects pointed to.

Results and Discussion

As a preliminary analysis we computed the mean number of questions asked by the subjects during the 30-minute interaction period. We found that the subjects asked a mean of 75.6 questions per session in the Design Instrument condition and 59.9 questions per session in the Assemble Band condition. Therefore, the rate of student questioning while using the P&Q interface was 135 questions per hour. This is about 7 times the rate of student question asking during normal tutoring (Person, 1990) and 800 times the rate of student questioning in a classroom environment. The high frequency of question asking using this software implies that the P&Q interface has the potential to radically encourage active learning when combined with educational software. However, more research is needed to substantiate this possibility.

The 30-minute interaction period was segregated into three 10-minute time blocks, yielding time block 1, 2, versus 3. We clustered the 10 question categories into four categories that addressed four different types of knowledge: taxonomic-definitional , sensory , procedural, and causal. An analysis of variance was performed on question asking frequencies using a mixed design with three independent variables: condition (Design Instrument versus Assemble Band), time block (1, 2, versus 3), and question type (taxonomic-definitional, sensory, procedural, and causal).

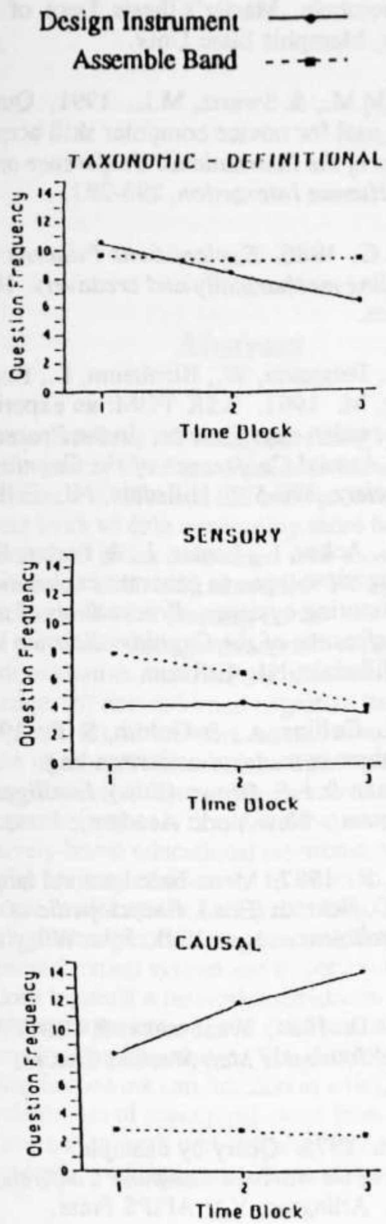
We first analyzed the main effects in the ANOVA. The frequency of questions did not significantly vary as a function of time blocks, with means of 22.8, 23.4, and 21.2 questions in time blocks 1, 2 and 3, respectively. Therefore, the volume of questions was approximately constant across the three 10-minute segments, indicating a constant level of student curiosity and initiative. More questions were asked in the Design Instrument condition than in the Assemble Band condition, $F(1, 28) = 5.00$, $p < .05$. The number of questions per time block significantly differed among the four question types, with means of 8.8, 5.3, 1.1, and 7.3 for taxonomic-definitional, sensory, procedural, and causal knowledge questions, respectively, $F(3, 84) = 27.62$, $p < .05$. This result is not surprising, however, because the baserate frequency of available questions was quite different among the four question types.

There was a significant three-way interaction between condition, time block, and question type, $F(6,168) = 2.89$, $p < .05$. Figure 2 plots the cell means that expose this three-way interaction. The following trends explained the interaction:

Taxonomic-definitional

The frequency of these questions were about equal for the two conditions in time block 1. The frequency of this question type decreased over time in the Design Instrument condition, but remained constant in the Assemble Band condition. This would indicate that the learner must acquire taxonomic and definitional knowledge of a domain during the initial learning phase, regardless of the learner's goals. As learning progresses, the learner asks questions that are more directly related to the learning goal.

Figure 2. Questioning frequencies for different types of knowledge.



Causal

The frequency of this type of question was extremely high and increased over time in the Design Instrument condition, whereas the frequency was extremely low and constant in the Assemble Band condition. It appears that student initiative in asking causal questions is directly affected by learner goals. Deep level causal knowledge was required to satisfy the task in the Design Instrument condition, and the student was forced to ask many causal questions. Deep level knowledge was not required in the Assemble Band condition, so the subjects did not try to acquire this knowledge.

Sensory

The frequency of sensory questions was low and constant in the Design Instrument condition. The frequency was initially high in the Assemble Band condition but decreased robustly over time. The subjects in the Assemble Band condition wanted to find out what the instruments looked like and sounded like very early in the learning process. This superficial knowledge was necessary for the spatial and aesthetic considerations involved in assembling a band, whereas causal knowledge was unimportant.

Procedural

There was a floor effect for this type of question so it was difficult to decipher trends. Subjects in the Assemble Band condition asked approximately twice as many questions in this category as did subjects in the Design Instrument condition.

Conclusion

This study has documented how a P&Q computer learning environment can stimulate student initiative and questioning. Initiative was measured by the frequency and type of student questions. We found that in a computer environment designed around questioning, students were capable of taking a very active role in the learning process. We have also presented evidence that some student questioning patterns are directly affected by the student's learning goals, whereas other patterns are comparatively impervious to their learning goals. Students are capable of actively monitoring the acquisition of knowledge in a domain, and adjusting this acquisition to satisfy their goals.

The P&Q interface and other similar new interfaces (Schank et al., 1991; Sebrechts & Swartz, 1991) have made it extremely easy for the user to ask questions. It is possible that interfaces like these could have a substantial impact on education to the extent that they rekindle curiosity and good question asking skills. Students can and will take the initiative in the learning process, if given the right environment.

The P&Q interface represents a radical approach to educational software. The only action allowed is question asking, and the student has full initiative in the learning process. As research progresses and the interface evolves, we intend to shift the initiative, allowing for a more realistic mixed-initiative dialogue. Additional research is required to uncover the system's full potential as a learning tool.

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