Exploratory question posing: Towards improving students' knowledge integration performance

Shitanshu Mishra*

Indian Institute of Technology Bombay, India
E-mail: shitanshu@iitb.ac.in

Sridhar Iyer

Indian Institute of Technology Bombay, India
E-mail: sri@iitb.ac.in

*Corresponding author

Abstract: When students encounter new knowledge it is fragmented and fragile, not well connected to their existing knowledge. It is highly desirable that students integrate the knowledge pieces effectively. Traditional teaching–learning does not explicitly target improvement of students' knowledge integration. This paper shows the results of the first two cycles of an ongoing design-based research project that aims at devising a technology enhanced learning environment (TELE) to improve students' knowledge integration performance. The TELE is based on exploratory question posing activities, which involves the asking of new questions around a given concept. We anticipate that by the end of this design-based research we would be able to contribute with an effective online intervention to improve students' knowledge integration performance. Further we will analyze what are the mechanisms which lead to this improvement. The research is being carried out in data structures domain and the target population is engineering undergraduates.

Keywords: Question posing; Knowledge integration; Performance

1. Introduction

Knowledge integration (KI) is defined as the process by which learners sort out connections between new and existing ideas to reach more normative and coherent understanding in science (Liu, Lee, Hofstetter, & Linn, 2008). It is the ability to use theory or evidence to create a linked and coherent argument (Baxter & Glaser, 1998; Nichols & Sugrue, 1999; Shepard, 2000). Due to this emphasis on the coherence across science ideas KI leads to deep understanding in science (Linn, 2006). The process of making links and forming arguments results in a more organized understanding of the concepts (Lee, Liu, & Linn, 2011). It follows the constructivist view of learning and is based on extensive research on science instruction (Linn, 2006; Linn, Davis, & Bell, 2004). According to the connectionist theory of cognition (Fodor & Pylyshyn, 1988), if a concept is represented in the brain by a complex network including connections to multiple contexts and modalities, the learner has an opportunity to access, manipulate and use the concept in several ways in problem solving and inquiry. However for these connections to form a coherent representation, KI is required.

To the best of our knowledge traditional teaching–learning strategies do not explicitly target improvement of students' KI. This paper shows the results of the first two cycles of an ongoing design-based research that aims at designing a technology enhanced learning environment (TELE) to improve students' KI performance. The TELE is based on exploratory question posing (QP) activities, which involve the asking of new questions around a given concept. In addition to designing the TELE the overall research goal of the DBR is also to investigate what are the mechanisms which lead to the improvement of KI. Fig. 1 shows the overview of DBR cycles.

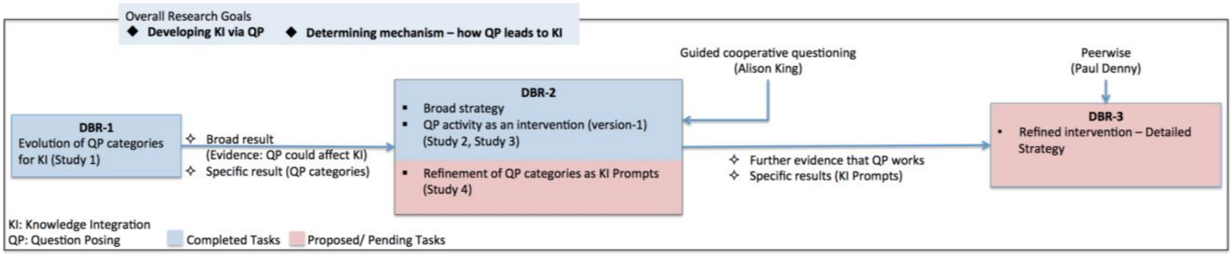


Fig. 1. Overview of DBR cycles

From cognitive science perspective it appears that questions are the 'indicators' of exploration. The integration of concepts is caused by (if anything) the exploration process, which comes before and after the questioning. Studies done by King and Rosenshine (1993) also suggest that questioning can promote connections between the concepts. With this background we investigated how does questioning activity provides affordance for knowledge integration. This lead to the first cycle of our design based research (DBR), which we would be discussing in the subsequent section. In the second DBR cycle it we have got qualitative evidence that questioning affects the deep learning and knowledge integration. To quote a few students' feedbacks on how did the questioning activity affected their learning:

(i) "Learning 'how to question' would help in understanding the concepts better."

(ii) "We can think about a topic in different ways and therefore can learn more concepts at the same time."

(iii) "It made us to explore more into the topics and making better questions of each things..."

(iv) "It made us to learn the thinking process... given a concept, how to deeply look into it…".

(v) "Workshop [activity] helped in given any data, video, lecture, how to assimilate it and extract important things out of it."

2. Design based research (DBR)

As shown in Fig. 1, studies in the first DBR cycle (DBR-1) provided broad evidence that QP is the indicator of KI and can affect KI. Another important outcome of the DBR-1 is the questioning categories, which were used as the question prompts in the first version of the intervention. In the second DBR cycle (DBR-2) we designed an intervention where QP activities were based on the guided cooperative question model proposed by King and Rosenshine (1993), which used the questioning categories as question prompts. The

DBR-2 contained a total of 3 studies – first one was to test the effectiveness of the QP intervention; the second was to qualitatively investigate how QP was helpful to KI, as perceived by the students and the third was to refine the QP categories by analyzing a larger question-corpus. This analysis is under progress and will lead to the final KI-prompts, which will be used in the next version of the intervention. The results of the first two studies are presented in the subsequent section. In the third DBR cycle (DBR-3) we propose to design and test the next version of the intervention. It will use the KI-prompts obtained from the study-4 of DBR-2, and we use some ideas from the activity of question sharing and discussion as proposed in PeerWise (Denny, Luxton-Reilly, & Hamer, 2008). In the subsequent sub-sections we describe the work done in DBR-1 and DBR-2.

2.1. DBR cycle 1

The research objective of the first DBR cycle was to investigate how question posing affords KI. We conducted three QP sessions: two in a data structures (DS) course and one in an artificial intelligence (AI) course and collected a corpus of 104 student-posed questions. We performed first set of inductive qualitative analysis of this corpus to find out that there are two types of knowledge (or concepts) present in any question: (i) The knowledge delivered explicitly in the video lecture. We call it "given" knowledge, and (ii) The knowledge not delivered explicitly in the video lecture. We call it "prior" knowledge. There were few questions, which aimed at explicit reiteration of the content of the video lecture and did not have any prior knowledge. We call them clarification questions (Mishra & Iyer, 2015). All other questions, which lead to unfolding of a new concept, are called exploratory questions. We also found that every exploratory question exhibited certain association between the prior and the given knowledge. With this information we performed a second set of inductive qualitative analysis of the same corpus to answer our research question: “How do students integrate prior knowledge and given knowledge to arrive at a question during question posing?” Open coding and axial coding (Strauss & Corbin, 1990) were carried out separately for each of the question sets (DS and AI questions). This helped in testing if the results of the axial coding are valid across the Computer Applications domains (DS and AI). This qualitative study has been reported in detail in (Mishra & Iyer, 2015). At the end of the analysis there were seven evident strategies by which students integrate their prior knowledge and the given knowledge to come up with exploratory questions. These seven strategies are further grouped into three classes of the exploratory questioning: 1) *Employ*, where students integrate the concepts from given knowledge with some goal ‘application’ or ‘structural arrangement’. 2) *Associate*, where concepts from given and prior knowledge are integrated to seek insight about the given knowledge or prior knowledge. 3) *Operate*, where the QP involves integrating given knowledge with known goal state (or modifications) and seek operations/procedure to achieve the goal state. The examples of these three questioning classes, with “arrays” as a concept from the given knowledge (video lecture) respectively are: 1)"Can I create social network graph using array?” (Employ); 2) ”How bad is array than the structures when it comes to using less memory?” (Associate); “How can I search a value from the list of values stored as an array?” (Operate). This has given us evidence that the exploratory QP process involves the knowledge integration process.

2.2. DBR cycle 2

In the second DBR cycle we aimed at investigating the research question: “What is the effect of questioning activity on students’ KI. Fig. 2 shows the learning-strategy (and the research design) of the study-2. The study was conducted with 24 first year computer science-engineering undergrads. There were 12 students each in control and experimental groups. In the start students were given a 1 min and 26 sec long video on how to make a simple concept map (CMap). This was important because assessment is completely concept mapping based and students had no prior exposure to either to CMAP tool or to CMaps. The "Watch" activity was about watching a 17 minutes long video lecture on "Linked List". Students were allowed to seek the video back and forth and watch the video as many times as they want, within the stipulated maximum time. In the *phases 2, 3 and 4* students read slides on different questioning types (clarification and exploratory) and different questioning prompts, they posed questions around the content of the video and they shared and face-to-face discussed their questions. There was no specific script and control to what students were discussing. The control group got double time to watch the same video lecture. In the posttest students were given parking lot of the keywords from the video lecture they watched and were told to create CMaps to reflect what they learnt in the "linked list" video. The CMaps submitted in the posttest were used to assess KI performances of the students. The rubric proposed by Liu et al. (2008) for assessing the knowledge integration construct was adapted for evaluating CMaps. The four ordered levels of KI performances given by Liu et al. (2008), viz., Score 0 for "No Link", Score 1 for "Partial Link", Score 2 for "Full Link", Score 3 for "Complex Link" were mapped to the four criteria in a CMap. Following criteria were evaluated in any CMap: (1) count of triplets, (2) count of valid triplets (partial link), (3) count of partial links having extension by at least one node (full links), (4) count of full links having extension by more than one node (complex links). Here one triplet refers to a pair of two concepts connected with one link. The comparison of the two groups on each criteria of the rubric is shown in Fig. 3. Though it wasn't statistically significant, the result gives a trend that the questioning group scored higher than the control group. The qualitative feedback collected in the study-3 gives an account of the students' perceptions that the questioning activity helped them in: *"deep thinking"*, *"relating the concepts to prior knowledge"* and *"self-examining understanding."*

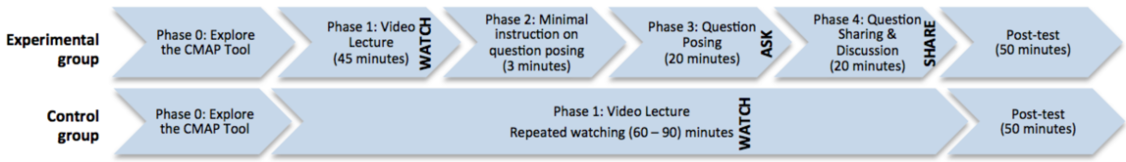
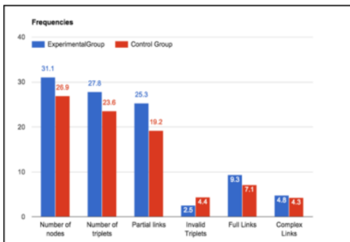


Fig. 2. Activities in the study-2 of DBR-2



	Nodes	Triplets	Valid triplets	Invalid triplets	Full links	Complex links
Mann-Whitney U	50.50	42.00	40.00	41.50	61.50	72.00
Wilcoxon W	128.50	120.00	118.00	119.50	139.50	150.00
Z	-1.24	-1.74	-1.85	-1.79	-.61	.00
P (2-tailed)	.213	.082	.064	.073	.541	1.000

Test Statistics, $N^{experimental} = N^{Control} = 12$

Fig. 3. Result from the Study-2

3. Experienced challenges and main strategies

One of the major challenges at the start of this DBR project was that we didn't have any theoretical insights regarding how student's questioning can be tailored to suit knowledge integration/ deep learning. We performed inductive qualitative research with a very broad research question, "what do students do while posing questions as evident from the question artifacts generated by them?" This exploratory qualitative research gave us the insight that students attempt to integrate their prior knowledge with the given knowledge. After this confirming evidence we moved ahead and repeated the data analysis with a more specific research question, "What are the different patterns in which students integrate knowledge pieces while generating questions?"

Another challenge in this project is about capturing what exactly goes on inside the minds of students while generating questions. This is important because we have to identify the mechanisms that lead to students' improvement of knowledge integration. For this we use the artifacts generated by the students, which includes generated questions, and discussion logs along with student interviews and perception surveys. Given a non-trivial construct of knowledge integration, the challenge is to structure interviews and surveys such that they can elicit the mechanisms of knowledge integration without biasing or complicating the reflection process of the students. We need to delimit our claims to the kind of inferences that our collected data affords.

In some of the pilots we found that when the intervention is too long then students' engagement with activities fade with time. For example, in one of the pilots we wanted to administer the perception survey and interview on the day of the intervention. The intervention plus a posttest requires 2 hours of students' engagement and a pretest would add 30 more minutes. In this situation when we asked students for their qualitative feedback we found that students were reluctant to give deep responses. After this experience we decided to split the data collection into two separate studies. This is the reason why we did separate studies (in the DBR-cycle-2) for collecting students' feedback about the effect of the questioning process on their learning. In the DBR-cycle-3 we propose to conduct smaller pilots to do qualitative studies of our final strategy and a big quantitative study to measure the effectiveness of the strategy. The follow-up challenge in this methodology is to ensure that the split studies are done with equivalent samples. Moreover, the challenge of ensuring cohort equivalence is even more prominent as cohort changes are inevitable across the DBR cycles because the DBR cycles take longer to implement, usually multiple years.

Another set of challenges are concerned with the domain expertise of the researcher. The inductive qualitative research could have not been possible if the researchers (data analysts) did not have domain knowledge of computer science. In fact for checking for reliability the co-analysts should also have domain knowledge. So to establish the generalizability of the knowledge integration prompts we propose to partner with domain experts outside computer science domain. By the end of this DBR project we intend to test (if not ensure) that the evolved knowledge integration prompts are generalizable to other CS topics and to other domains. To achieve this we will repeat similar QP exercises with the students of other domains and validate if the KI prompts are applicable to the QP in other domains.

One of our goals is to situate KI in an authentic inquiry task. It is difficult to ensure that students have authentic engagement with the activities. In the DBR-cycle-2 for example, we found that not all students actually use the prompts to do the questioning activity. The possible strategies to address this challenge are: (i) structure the activities such that it becomes inevitable for the students to engage with the prompts; (ii) provide students motivation, such as scores/points. In the DBR-cycle-3 we are working more on structuring the activities.

4. Conclusion

In this paper we have reported design, implementation, results and associated challenges of an ongoing design-based research project. By the end of this DBR project we aim at developing a TELE to improve students knowledge integration performance. The TELE shall provide a synchronous online learning environment wherein students shall do QP and reflection activities based on meta-cognitive KI-prompts. The completed studies have been implemented in semi-online mode. Total 4 studies have already been done, and data from 3 studies have been analyzed. The results till the current progress of the DBR shows that question posing is not just an indicator of KI but has potential to improve KI performance.

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