Students' Questions as an Indicator for Embracing a Problem-Based Learning Environment: Case Study

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ABSTRACT

The purpose of this study is to identify whether students’ questions can be utilized as an indicator of the degree of students’ embracing a Problem-Based Learning (PBL) environment. Based on a case study approach, students’ questions were recorded throughout a PBL course and analyzed over time regarding frequency of questions, occurrence of types of questions, relationship between questions and students’ projects and types of stimuli. The distribution of the total of 249 recorded questions over time, as well as the type of questions asked indicate that students tend to focus on project work, but procrastinate preparation of their portfolios for the summative assessment at the end of the semester. Furthermore, the smaller number of questions during the second part of the course may indicate that students had a better understanding of the nature of PBL and were able to work and learn with greater confidence. From this study, the indications are that engineering educators and educational institutions need to be aware that students need time to experience a full cycle of PBL in order to fully embrace this type of approach.

Key words: Problem-Based Learning, PBL, active learning, student question, learning environment.

INTRODUCTION

Problem-Based Learning (PBL) and similar learning approaches found considerable interest in engineering education and other fields. This study aims at analyzing engineering students’ questions that were asked while they were exposed to PBL for the first time, in order to find out if students’ questions are an indicator of the degree students embraced the new learning environment. In the following, PBL was summarized, followed by the purpose and method of this study in order to provide the foundation for the analysis and discussion of the collected student questions, as well as the conclusions.

The PBL approach originated at McMaster University (Graaff and Kolmos, 2007; Richardson and Delaney, 2010) and the characteristics of PBL were summarized (Savery, 2006):

- Students must have responsibility for their own learning;
- Problem simulations must be ill-structured and allowed for free inquiry;
- Learning should be integrated from a wide range of disciplines;
- Collaboration is essential;
- What students learn during their self-directed learning must be applied back to the problem with reanalysis and resolution;
- A closing analysis of what has been learned from work with the problem and a discussion of what concepts and principles have been learned is essential;
- Self and peer assessment should be carried out at the completion of each problem and at the end of every curricular unit;
- The activities carried out must be those valued in the real world;
- Student examinations must measure student progress towards the goals of problem-based learning; and
- Problem-based learning must be the pedagogical base in the curriculum and not part of a didactic curriculum.

Different variations, models and perspectives on PBL emerged (Graaff and Kolmos, 2003) and led to approaches such as “Problem-Oriented and Project-Based Learning” (Lehmann et al., 2008) and “Problem-Based Project-Organized Learning” (Garcia et al., 2011). The common focus of the different PBL variations and models is learning around problem scenarios rather than discrete subjects (Savin-Baden, 2000: 3). The problem scenario could be a badly structured situation tackled as a project (Project-Based Learning), or could be a case (Case-Based Learning) as it is common in medical education, psychology, social science or science education (Dochy et al., 2003; Kolmos et al., 2009).

Most PBL models are classified as “hybrid models” since they include aspects of traditional learning approaches such as lectures (Boud and Feletti, 1997; Savin-Baden, 2000). PBL has been shown to stimulate critical thinking, self-learning skills, life-long learning, self-achievement, self-regulation, self-efficacy, communication skills, interpersonal skills and students’ motivation (Guerra and Kolmos, 2011).

However, how quickly and how well do engineering students embrace their PBL environment while they are exposed to the PBL approach for the first time? Do students’ questions asked during their PBL course present a usable indicator?

Purpose

The purpose of this study is to identify if questions from students who are exposed for the first time to a PBL environment may be utilized as an indicator for their embracing of the new learning environment. The following questions shall be answered:

1) How does the frequency of questions vary with time over the period of the course?
2) Can different categories of questions be identified and how does the frequency of questions within each category develop over time?
3) How many student questions are clearly related to each of the students' projects?
4) How many student questions are asked repeatedly over time?
5) Can different stimuli be identified that trigger students’ questions and how does the number of questions by type of stimulation develop over time?

MATERIALS AND METHODS

Case study approach

In order to meet the purpose of this study, a case study approach was chosen. This requires clarifying whether a single case study or multiple case studies are necessary. Yin (2003) describes five criteria, any of which make a single case study appropriate:

1) The case is critical and allows testing a well formulated theory;
2) The case is unique or extreme;
3) The case is representative or typical;
4) The case allows analysis of a previously inaccessible phenomenon; and,
5) The case is longitudinal in nature (that is, covering an extended period of time) and allows analysis at different points of time (Yin, 2003: 39–46).

For the case considered here, criteria 2 to 5 are met as follows:

- For the students considered here, it was their first PBL course. Furthermore, ideas for this course were received from an institution of a different cultural background and further adjustments to the course based on the cultural setting of the case considered here were to be expected;
- The case is typical for all students who study the PBL course considered here. Regarding the type of questions students asked, similarities can reasonably be expected for other “first time PBL courses” at other institutions;
- The phenomenon of students’ questions can only be studied qualitatively by looking at the question content, quantity and relationships; and
- The case is longitudinal in nature, that is, the case covers a whole semester and questions were analyzed at different time points during the semester.

Hence, a single case study is considered appropriate for the purpose of the research considered here and the data collection process is in line with the principles of the case study research (Yin, 2003: 83–108), in that direct observations (that is, observation of students’ questions) were analyzed.

The case considered here

The cohort consisted of 49 undergraduate engineering students (mechanical and civil engineering) enrolled in a third year PBL course “Engineering Skills” at a private college in the Arabian Gulf region. The average age of the students was 23 years, 28% were female students and 72% male. A majority of 92% of all students did not have prior work experience, and the four students with work
experience did not work in civil- or mechanical-engineering related fields. Webb (2008) showed that critical enquiry is comparatively absent in educational institutions in the Arabian Gulf and that the educational system prioritizes rote learning over analytical investigation (Webb, 2008). For all students, it was the first time they were exposed to PBL. Table 1 shows the learning outcomes of the course.

Learning was embedded in given scenarios, based on the following six group projects. Each group consisted of 4 to 5 students:

- Design, build and test simple water filter (Project 1);
- Research and present an engineering invention or disaster (Project 2);
- Design, build and test concrete bricks for building shelter in an earthquake area (Project 3; hands-on project);
- Develop and present a computer program based on a given technical standard (Project 4);
- Design, build and test a device to produce disinfected water in an earthquake area (Project 5; hands-on project); and,

The course, “Engineering Skills”, was split up in two parts, in the following labeled “Skills 1” and “Skills 2”. This allowed providing students with a grade after being halfway through the course and similar to the effect of mid-term examinations in traditional courses in that students understand their current level of performance and still have time left to show improvement. In week 7, a summative assessment was used to assess students learning during “Skills 1” and in week 13, a second summative assessment was used to assess students learning during “Skills 2”. For the summative assessments, students had to submit portfolios that included the following items:

- Reflective Journal showing thoughts on learning and the learning process;
- Workbook showing work related to the projects (incl. meeting minutes, sketches and project reports, etc);
- Drawing folder of technical drawings related to the projects;
- Peer- and self-evaluation;
- Individual grade nomination; and
- Reflective paper on a given engineering project.

Formative assessment took place on a continuing basis by providing feedback to students on their project work and preparation of portfolio items. The learning facilitators (one lecturer and two teaching assistants) evaluated the students’ learning based on criteria related to the learning outcomes and each student had to undergo an individual viva voce in order to discuss their portfolio. Table 2 shows due dates of students’ projects (1 to 6) and portfolios.

### Data collection

Students’ questions were recorded during the entire course, starting during week 2. In week 1, not all students had registered and therefore, the class session was limited to an introduction without an extended Question/Answer (Q/A) session. From week 2 to 12, all scheduled class sessions (3 per week) started with a Q/A session before students continued with their group work.
Table 2: Due dates of projects and portfolios.

<table>
<thead>
<tr>
<th>Week</th>
<th>&quot;Skills 1&quot;</th>
<th>Week (cont.)</th>
<th>&quot;Skills 2&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>9</td>
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<td>6</td>
<td>2, 3</td>
<td>12</td>
<td>5, 6</td>
</tr>
<tr>
<td>7</td>
<td>Portfolio 1</td>
<td>13</td>
<td>Portfolio 2</td>
</tr>
</tbody>
</table>

Figure 1: Number of questions per week – "Skills 1" versus "Skills 2".

RESULTS AND DISCUSSION

The following results are discussed according to the sequence of the research questions that were earlier shown.

Questions over time

With the aim of answering the first research question (That is, how many questions were asked over time?), the total number of 249 questions that were asked during the course were shown over time and compared between “Skills 1 and 2” (Figure 1). These questions included questions such as:

1) Can I type my workbook?
2) Do we add meeting minutes to the workbook?
3) How do we do meeting minutes?
4) Do we submit a professional report?
5) Do we need to record the time for concrete curing?
6) Do we have to put a tank on the roof for the house in Haiti?
7) Are there standards we should follow?
8) When do we get the material for Project 3?
9) At which times can we use the workshop?
10) Do we need to cover meetings in Reflective Journal and Workbook?
11) Can I present a disaster and an invention for Project 2?

In “Skills 1” (That is, week 1 to 7), students asked:

- 39 questions in week 2;
- A maximum of 52 questions in week 3;
- 19 questions in week 6; and
- 29 questions in week 7.

In “Skills 2” (That is, week 8 to 13), the total number of questions asked is clearly less than the total number of questions during “Skills 1”. Also, the number of questions per week during “Skills 2” is below the number of questions per week in “Skills 1” for all weeks. Students asked:

- 6 questions in week 8;
- A maximum of 13 questions in week 10;
- 2 questions in week 2; and,
- 12 questions in week 12 - the last week of class sessions in "Skills 2".

The lower number of questions during “Skills 2” seems to indicate a learning effect. Since students’ projects during
“Skills 2” were different than the projects carried out in “Skills 1”, the learning effect may have been related to preparing portfolio items or the general mode of learning based on projects. The number of questions developed was similar qualitatively in both parts of the course: After increasing at the beginning, the number of questions decreased to a minimum of two weeks before students’ portfolios were due and increased again one week before students’ portfolios were due. A reliable interpretation of these trends and the difference between “Skills 1 and 2” requires considering the types of questions asked and this will be given after the types of questions are analyzed.

**Groups of questions**

In order to answer the second research question (That is, can different groups of questions be identified and how does the number of questions within each group develop over time?), the complete list of collected questions was first analyzed regarding the questions’ content. Based on a common theme, four different categories of questions were identified:

1) 108 questions related to the portfolio items (in the following called “portfolio-related questions”; “Skills 1”: 85 questions, “Skills 2”: 23 questions);
2) 39 questions related to necessary knowledge in order to carry out projects (in the following called “project knowledge-related questions”; “Skills 1”: 34 questions, “Skills 2”: 5 questions);
3) 93 questions referring to project-related instructions that were either part of the written project descriptors or given during class sessions (in the following called “project instructions-related questions”; “Skills 1”: 79 questions, “Skills 2”: 14 questions); and
4) 9 “other questions” that were not related to the delivery of “Skills 1 and 2” (as a consequence, they are not further considered here).

Each of the first three groups of questions is analyzed in detail. The number of portfolio-related questions (Figure 2) reflects a similar trend over time for “Skills 1 and 2”. The trend is also similar to the earlier total number of questions per week (Figure 1). At the beginning, the number of questions is increasing (except “Skills 1”: where the number is first slightly decreased from 12 to 9 questions, before it increases to 19 questions). In week 5 and 11, the number of questions decreased. At the end of “Skills 1 and 2” the number of questions is again increased.

The number of project knowledge-related questions (Figure 3) reflects a different trend. For “Skills 1 and 2” the numbers of questions are first increased and then again decreased. For “Skills 1”, the number of questions reaches a maximum of 15 questions in week 3 and for “Skills 2” the maximum is 2 questions in weeks 10 and 11.

The number of project instructions-related questions (Figure 4) reflects a similar trend to the previous project knowledge-related questions. However, these questions were asked earlier than the project knowledge-related questions. The five questions asked in week 7 were already related to projects for “Skills 2”. The total number of project instructions-related questions was with 93 questions which is larger than the project knowledge-related questions with 39 questions.

For these three categories of questions (That is, portfolio-related, project instructions-related and project knowledge-related) the distribution of questions over time can be interpreted as follows: Students approaching the portfolio submission deadline is the main reason for the increased number of portfolio-related questions towards the end of “Skills 1 and 2”. This was confirmed by observations of the
learning facilitators. Although students could have started earlier to prepare their portfolios, they gave priority to the project work and started late with preparing their portfolios. This had a detrimental effect on the quality of their portfolios since they did not remember all areas of reflection and all project related details they had thought through at some point in time. While students were reminded throughout the course to prepare their portfolios parallel to their project work, they tended to ignore this advice.

The project submission deadline in “Skills 1 and 2” did not increase the number of project-related questions when approaching the deadlines. This confirms the observation of the learning facilitators that students started working on their projects as soon as possible. The relatively small number of project knowledge-related questions (compared with the projects instructions-related questions) might reflect students’ understanding that it is their responsibility to identify and master required knowledge and skills in order to carry out students’ projects. However, it may also indicate that their interest in grades is higher than high quality projects. Most of the project instructions-related questions were related to students’ lack of awareness regarding industry practice. Therefore, students’ were repeatedly encouraged by the learning facilitators to seek contact with practitioners and discuss typical approaches.

Questions related to projects

In order to answer the third research question (That is, how many questions are clearly related to each of the students’ projects?), the links of questions to one of the five projects were analyzed (Figure 5). The largest number of
Figure 5: Number of questions per project and week (numbers only shown for the two hands-on projects).

Project-related questions (both, project knowledge-related and project instructions-related) was related to Project 3 (the hands-on project during “Skills 1”). A maximum of 38 questions was asked in week 3, whereas only 3 project-related questions were asked regarding Project 5 (the hands-on project during “Skills 2”) in week 10. The number of questions related to Projects 1, 2, 4 and 6 were found in both “Skills 1 and 2” similar and comparably small.

The following three reasons were identified for the larger number of questions in “Skills 1”. First, for all of the students it was the first time that they had to manage and carry out a group project without much guidance. They were not familiar with the situation and these triggered questions such as the following:

- Where are we producing the molds?
- Can we ask an engineer?
- What about using additives?
- Can we do trials?
- Shall we make a schedule for Project 3?

These types of project instructions-related questions were not asked during Project 5. At the time of Project 5, students knew that the workshop was available for them, asking practicing engineers was encouraged and that most decisions were up to them and that time planning is an integral part of any project. Students were much more confident during Project 5 and made many decisions within their teams without involving the learning facilitators.

Secondly, students were tried to collect relevant knowledge from the learning facilitators by asking questions such as:

- Where is Haiti?
- Do we have to put a tank on the roof?

Thirdly, for Project 3, students were provided with material for the concrete bricks by the university, whereas they had to identify and supply material for Project 5. This difference in project delivery resulted in additional questions during Project 3, for example:

- How many rooms do we need?
- How can we build the house only with bricks?
- Does culture need to be considered in construction?

This happened in spite of the fact that students were informed in week 1 that knowledge-related questions will not be answered by the learning facilitators. These types of project knowledge-related questions were not asked during Project 5 since students had a better understanding regarding their responsibility.

In summary, the increased confidence among students, a better understanding of the nature of PBL and students’ responsibility to supply material contributed to a smaller number of questions related to the hands-on projects (That is, Projects 3 and 5).

Questions repeated over time

To answer the fourth research question (that is, how many questions are asked repeatedly over time, comparing “Skills 1 with 2”), the number of repeated questions over time has been identified (Figure 6). For “Skills 1”, the number
increases to six questions in week 3, before it decreases to zero questions in week 6 and increases to nine questions in week 7. For “Skills 2”, only in weeks 10, 11 and 12, one question was asked that had been asked before.

It needs to be considered that a repeated question may not necessarily relate to a lack of understanding. Rather, it may simply be the result of a student who missed a class session in which the same question was already answered before. However, looking at the type of questions that were asked repeatedly, it is apparent that the repeated questions up to week 4 were mostly project instructions-related questions. Questions repeated towards the end of “Skills 1” (that is, week 7) were portfolio-related questions. This is in line with the distribution of the total number of questions during “Skills 1” (discussion of question 1 earlier mentioned).

It confirms the previous interpretation of the second research question in that students’ focus on portfolio submission increases towards the portfolio submission deadline. However, the difference between “Skills 1 and 2” (Figure 6) confirms also the interpretation of the previous question: Students need to experience the nature of PBL in order to internalize it. Repeated explanations of PBL and the learning outcomes throughout the course are crucial (Jaeger and Adair, 2013). However, they do not ensure that students fully embrace the new learning environment. Students need time to develop confidence to work and learn within a PBL environment.

Stimulation of questions

Finally, in order to answer the fifth research question (That is, can different stimuli be identified that trigger students’ questions?), the content of each question was compared with the content of the previous questions asked during the same class session. Three different scenarios were identified:

1) The stimulation of the question asked could not be identified. The question may have been stimulated by previous group discussion, student’s own thinking, or a statement from one of the learning facilitators;
2) The question was stimulated by the previous question asked by another student;
3) The question was stimulated by an earlier question asked during the same class session.

This indicates that a student needed time to process the question earlier asked and/or the answer given, which led to a new, but related, question. Due to the interactive nature of the class sessions and based on the observations of students by the learning facilitators during the class sessions, the possibility of day-dreaming students was excluded.

Type of stimulation during “Skills 1”

The number of questions by type of stimulation is shown for “Skills 1” (Figure 7). They show that the largest number of questions in each week was stimulated by the preceding question. Towards the beginning of “Skills 1”, questions were more often stimulated by earlier questions than by unidentified stimulations. During the later period of “Skills 2” it was the opposite in that questions were more often stimulated by unidentified stimulations than by earlier questions.

Type of stimulation during “Skills 2”

The number of questions by type of stimulation is shown for “Skills 2” (Figure 8). It shows that no question was
stimulated by earlier questions. Furthermore, more questions were stimulated by unidentified stimulations than by preceding questions in each week.

The comparison of the number of questions by type of stimulation confirms the earlier interpretation of the number of question types (research question 2) and number of questions per project (research question 3): A learning effect regarding the PBL approach has taken place. Comparing the different stimulation types within “Skills 2”, most questions were “original questions”, that is, that were neither stimulated by earlier nor by preceding questions. Except at the beginning of “Skills 1”, there seems to be no difference regarding the stimulation types between times when questions focused more on projects and towards the end of “Skills 1 and 2”, when questions focused more on portfolios. Since students’ questions reflect the degree of interaction between student group members on the one hand and between students and the learning facilitators on the other hand, this seems to suggest that students took both the projects and the portfolios seriously. Nevertheless, students did not begin early enough to compile their portfolios in order to achieve higher portfolio quality.

On comparing the grade distribution of “Skills 1 with 2”, Figure 9 shows that in “Skills 2” a lower number of students failed and a larger number of students received higher grades. This confirms the previous interpretations in that
students embraced the PBL approach better during “Skills 2” than during “Skills 1”. The questions students asked seem to be a good indicator for their embracing of a new learning environment.

Limitations

The following potential threats to the validity of results were identified. The construct validity of the research presented here might be limited, since not all students asked the same amount of questions and although attendance was very high, not all students were present in all class sessions. Furthermore, the analyzed results are derived from the case considered here, but they maybe different for students of a different socio-economic context and coming from a different learning background. Therefore, the exploratory character of the research presented here needs to be recognized and following further investigations may lead to more generalized future results.

Conclusions

In order to identify if students’ questions during a PBL course indicate a degree of embracing PBL, students’ questions during their first PBL course were recorded and analyzed. The distribution of questions over time showed that fewer questions were asked during the latter part of the course. The number of project instructions-related questions as well as portfolio-related questions decreased. Analysis of the type of questions asked indicated that students focused on project work, but procrastinated preparing their portfolios. Furthermore, the type and amount of projects instruction-related questions indicated a lack of awareness regarding industry practice. Finally, the decreased number of questions during “Skills 2” (week 8 to 13) indicated that students had a better understanding of the nature of PBL and were able to work and learn with greater confidence compared with “Skills 1”. This was also reflected in higher grades for “Skills 2”.

Engineering educators and educational institutions need to be aware that mere explanations of PBL at the beginning and throughout a course are not sufficient. Rather, students need to experience the PBL environment in order to understand their responsibilities in carrying out projects and preparing their learning portfolios.

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