Targeting Misconceptions Using Socratic Questioning

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Abstract

Misconceptions pose a great barrier to learning and often lead to frustration with the subject. Students are usually either unaware of the misconceptions or have difficulties dismissing preconceived notions and ingrained nonscientific beliefs. This study investigated the use of socratic questioning to help students identify, confront and correct misconceptions they may have while studying a chemical engineering subject. Comparisons were made on the two groups' performance in calculation-typed and conceptual-typed of questions in the examinations. In general, both control and treatment groups of students were equally capable in answering calculation questions. However, there was a significant gap in the two groups' abilities to answer questions which required conceptual understanding. The group of students who was not taught socratic questioning did not perform as well in answering conceptual questions even though they were able to do the calculations correctly. This showed that some students often memorize steps, equations, problem-solving skills without thorough understanding of concepts. Students reported in the survey that they found socratic questioning useful in helping them to clear their doubts and misconceptions. The focus group discussion with the students revealed that as the students were used to rote learning and they needed time and training to be comfortable with using questioning for metacognitive learning. The results from the study highlighted the importance of providing a platform for students to identify, confront and break down misconceptions as well as helping students reconstruct and internalize their knowledge, instead of delving into solving the problem.

1. Introduction

Many students have misconceptions about what science is and how it works. Some of them do not even know that their ideas are incorrect. These misconceptions pose a great barrier to learning and lead to frustration with the subject. Eventually the students resort to rote learning and correctly-memorized answers. When questioned further, these students reveal their failure to understand fully the underlying concepts even though they may be able to give correct numerical answers.

Literatures have reported the need to adopt strategies in helping students overcome their misconceptions. One study found that teachers need to understand both the content they are trying to convey and more importantly, the specific misconceptions students have in order to improve science instruction [1]. The key to success is ensuring that students are constructing or reconstructing a correct framework for their new knowledge. This process requires the teacher to identify students' misconceptions, to provide a forum for students to confront their misconceptions and to help students reconstruct and internalize their knowledge, based on scientific models [2]. According to Lovett [3], effective teaching must engage prior conceptions and learning to the greatest extent possible. It is also important to leverage students' accurate knowledge and help students to connect them with new information to promote learning; to identify and fill gaps in students' understanding; to recognize when students are applying prior knowledge inappropriately; to actively work to correct misconception; and to avoid making inappropriate associations in learning.

This study aims to help students to discover and overcome their misconception about science and engineering knowledge using socratic questioning so that they can connect and organize their new knowledge meaningfully as well as appreciate and apply their learning with deep understanding. This study also generates new insights on how socratic question can be used effectively for enhancing learning of science and engineering topics.

2. Tackling Misconceptions

Misconceptions can be referred to as conceptual misunderstanding or preconceived notions that are false. These are cases in which something a person knows and believes does not match what is known to be scientifically correct.

Students who hold misconceptions about science concepts may not even know that their conceptions are incorrect. While having preconceptions is inevitable, the preconceptions they hold – particularly the incomplete and inaccurate ones – can present challenges to learning [4]. This problem escalates as the students advance into higher level as any misconceptions that students harbor may impede

further learning [5]. One, the students often have a hard time giving up their misconceptions, even when they are shown that the concepts are wrong, especially if they have had a misconception for a long time [6]. The longer a misconception remains unchallenged, the more likely it is to become entrenched and resistant to change [7]. Two, the misconceptions are barriers to learning because they either have difficulty fitting new learning with their current understandings which often lead to frustration with the subject [3] or, they will resort to rote learning and memorization, giving up on thorough understanding and meaningful learning [8].

The notion and impact of misconception on understanding science has been widely studied. The investigation ranges from physics [9][10] to schemata [11] to representation [12]. The National Academy of Science highlighted the issues of misconceptions being the barriers to understanding science [13]. It illustrated how “some of the best students give the right answers, but are only using correctly-memorized words. When questioned more closely, these students reveal their failure to understand the underlying concepts fully. Students are often able to use algorithms to solve numerical problems without completely understanding the underlying scientific concepts.” Similarly, Mazur [14] reported that the students in his physics class had memorized equations and problem-solving skills, but performed poorly on tests of conceptual understanding. Nakhleh and Mitchell [15] studied 60 students in an introductory course for chemistry majors. In an exam which paired an algorithmic problem with a conceptual question on the same topic, only 49 percent of those students classified as having high algorithmic ability were able to answer the parallel conceptual question.

3. Socratic Questioning

Socratic Questioning method, which is a constructivist learning approach, is identified as one of the most effective tools to probe deeper into one's hidden knowledge [16][17]. It starts with the recognition that preconceptions exist, and it then elicits the relevant preconceptions and then investigates the preconceptions by demanding their clarification. After clarification, one will be in better position to tests his or her own hypotheses and finally evaluate the preconceptions or judge a proposition in light of the given preconceptions. The method follows the way Socrates posed questions to his pupils. There are six types of questions which he used to challenge accuracy and completeness of thinking: conceptual clarification question, probing assumptions, probing rationale, questioning viewpoints and perspectives, probe implications and consequences and question the question [18]. This approach has been widely adopted and applied in a

variety of study fields like education, science, philosophy, psychology and medicine [2].

3.1. Types of Socratic Questioning

Based on the work done by Paul & Elder [19], the following six types of questions have been adapted for this study. Some sample questions are shown below:

1. Questions for clarification
“Can you give me an example?”
“Why do we add up resistance for heat transfer through composite layer?”
2. Questions that probe assumptions
“What is being assumed?”
“Why is the heat transfer area assumed to be perpendicular to the direction of flow?”
3. Questions that probe reasons and evidence
“Can you prove how this works?”
“Why do you think heat flows in the direction you have just drawn?”
4. Questions about viewpoints and perspectives
“What is another way to look at it?”
“What happen if heat transfer is not at steady state?”
5. Questions that probe implications and consequences
“What would this affect?”
“How would our calculations be affected if we have higher reflux ratio in distillation?”
6. Questions about the question
“Why do you think I asked this question?”
“Why do you ask if freezing is exothermic?”

4. Methods

4.1. Participants

Seventy-eight chemical engineering diploma students (mean age of 18 years old) in a public polytechnic participated in the study. 49% are female and 51% are male.

4.2. Design

The study took place over 15 weeks using one of the chemical engineering core modules - Heat & Mass Transfer. The students were taught socratic questioning technique during the 2-hour lecture on the first week. Examples were given to the students to help them appreciate how the six types of socratic questions can be applied to the module. In the subsequent lectures, dedicated time was given to students to apply socratic questioning on the module every week. Given real-life scenarios and open ended problems to solve during lecture, students were asked to work together in groups, discuss using

the socratic questioning techniques and arrive at a common consensus on the answers.

On top of that, all students were also asked to submit at least one question which would be addressed by the lecturer at the end of each lecture.

Students were assessed on their understanding of the module at the mid-semester and after the 15-week study semester.

Comparisons with the students from the control group which consists of 86 students from the previous cohort were made. 54% are female and 45% are male.

At the end of the semester, students were surveyed on the perceived usefulness and on the difficulties faced in using socratic questioning.

5. Results

At the end of the semester, the students had to answer four questions related to a scenario – two questions requiring the students to perform calculation of heat loss and two questions requiring the students to explain the concepts as well as the answers derived from the earlier calculations. Comparisons were made between the control and treatment groups in terms of their scores for the two types of questions.

With 6 marks being full marks for the calculation questions, the scores between the two groups were comparable (Figure 1 and 2) and more than 75% of the students in each group could perform the calculations correctly. The treatment group scored only slightly better (2% - 4% more receiving full marks for calculation questions) than the control group. In these two questions, no explanation was needed and students were only required to show the calculations steps and to use the correct formula.

Figure 1. Distribution of students' score in first calculation question

Figure 2. Distribution of students' score in second calculation question

Following the preceding part on calculations, students were asked to explain the meaning behind the numbers obtained from the calculations and provide reasons for a given alternate scenario. In these two questions, the students were required to show understanding of the concepts and its application.

There was a marked gap in the score on conceptual questions between the two groups (Figure 3 and Figure 4).

Figure 3. Distribution of students' score in first conceptual question

Figure 4. Distribution of students' score in second conceptual question

6. Discussion

In general, most students were able to answer calculation questions correctly with or without training in socratic questioning. However, the difference in the percentage of students being able to answer conceptual questions shows that the students could often perform calculations without fully understanding the concepts. This observation is consistent with what have been reported in studies on misconceptions being a barrier to understanding science [14]. Students often memorize steps, equations and problem-solving skills, but perform poorly on tests of conceptual understanding. Despite being able to give correct answer, when questioned more closely, they reveal their failure to comprehend the underlying concepts fully. It is only when students use questioning to probe into their hidden knowledge and investigate their preconceptions or assumptions made, they are able to connect, organize their knowledge meaningfully and apply their learning with deep understanding.

Through the survey and focus group discussion at the end of the semester, it was also observed that students are used to rote learning and need time to be comfortable in using questioning for metacognitive learning.

When asked about the difficulties faced in the process of using socratic questioning for the subject, most of them cited they struggled with coming up with questions to ask (Figure 5). This was especially when they were first asked to use socratic questioning, they either had problems thinking of a question or they felt that they had no questions to ask. This also explained another observation during the study - the treatment group performed significantly better than the control group only during final assessment but not during mid-semester in-course continual assessments. The students needed time and practice to improve questioning techniques and to be trained to pose deep questions instead of closed questions.

Despite the difficulties faced, 95% of the students in the treatment group were able to cite examples of usefulness of socratic questioning in their learning. 44% of the students quoted examples of how the “process of questioning clears my doubts”. 19% of the students reported that “the opportunity to ask questions made me turned on the inquisitive mode during lecture”. 15% of the students gave examples on how the “discussion with my friend corrects my misconceptions”. 5% of the students left the answer on usefulness blank or put “nil” as answer. The remaining students felt that socratic questioning either helped to deepen their knowledge on the subject or reinforce their current understanding. (Figure 6).

Figure 5. Difficulties faced in using socratic questioning

Figure 6. Students' example on usefulness of socratic questioning

The findings highlight the importance in helping students to challenge their misconceptions before any new material is introduced. Simply presenting a set of new knowledge will not produce conceptual change. To facilitate conceptual change, time must be set aside for students to be engaged in inquiry, so that they can ask probing questions, construct explanations, test their explanations against their friends, consider alternate explanations in order to construct knowledge effectively.

7. Conclusion

This study shows that socratic questioning techniques can be adapted and applied to fields beyond law and humanities. With the shift from lecturer-centered teaching to student-centered learning, didactic lectures can be turned into lively discussion amongst the students with the use of questions. In the next phase of study, research will be conducted on the use of socratic questioning in developing curious and inquisitive life-long learners.

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