**Science Education College Students Generate Questions as a Way of Learning**

**Abstract**

Student question-generation (SQG) is a constructive strategy that enriches learning, yet it is hardly practiced in higher education. The current study presents a potential model for integrating SQG in education, where 133 Science Education students from Israel practiced question-generation, followed by solving and peer assessment of the questions. An examination of the exam grades before and after SQG found that the activity did not result in a statistically significant improvement of achievements. However, a comparison of only of the achievements in solving the higher order thinking questions revealed an improvement in the students’ ability to cope with this type of questions. Moreover, the students reported additional advantages, such as productive group learning, and a question bank resulting from the activity, which helped the students in reviewing for the exam and reduced test anxiety. The educational implications of the findings are discussed in the article.

Keywords: Student questions; Question-generation; higher order questions

**Introduction**

Studies have shown that student question-generation (SGQ) promotes cognitive and metacognitive aspects of learning. This is an active learning activity and when done in groups, the social aspects of cooperative learning also enrich the learning experience (Yu 2012; Hardy et al 2014; Chin and Osborne 2008). But teachers do not tend to incorporate this activity in their teaching and students are focused on solving questions and hardly engage in question-generation. The activity is complex and difficult for both the teachers and the students for different reasons (Dori and Herscovitz 1999; Yu and Chen 2014; Shodell 1995; Woodward 1992). Consequently, there are few empirical systematic studies that deal with SQG compared to numerous studies that deal with teachers’ questions.

The importance of the current study lies in adding data and knowledge to the research field of SQG, as well presenting a potential teaching model for teachers in higher education that combines question-generating activities, as well as solving and peer assessment of students’ questions. The study participants were Science Education students from two colleges in the South of Israel. The students generated questions at different orders of thinking, assessed their peers’ questions, and compiled a question bank to review for an exam in the Cell Biology course. The effect of the practice on student achievements was examined, as well as coping with higher order questions, and the students’ opinions on question-generation.

**Literature Review**

***Questioning***

Questioning is at the foundation of learning and the students’ questions have a crucial role in meaningful learning and motivation to learn. In learning Science, questioning is a fundamental component of the research and problem solving process and one of the critical skills the students must develop ((Chin and Osborne 2008.In order to develop thinking, reasoning, and critical thinking, it is important to encourage questioning (Mason 2007; Zoller et al. 1997). Students’ questions, mainly in-depth questions, indicate that they are thinking about the topic, attempting to link the ideas to existing knowledge, and seeking comprehension (Watts and Alsop 1995; Furtak and Ruiz-Primo, 2008). The questions help to build the student’s knowledge, gradually lead to clarifying and establishing the information, discovering and completing the missing information (Biddulph, Symington and Osborne 1986) and increase the motivation to learn (Chin and Kayalvizhi 2005). The students’ questions also guide the teachers regarding the quality of the students’ knowledge, expose erroneous perceptions, what the students want to know, and may also influence what the teacher covers in the lesson (Watts, Gould and Alsop 1997; Chin and Brown 2002; Chin and Osborne 2008).

The question types and levels can be classified according to the required order of thinking to answer the questions. One of the most commonly accepted classifications in Bloom’s Taxonomy (Bloom et al. 1956), which offers a hierarchy of questions ranging from knowledge questions, expressing the lowest order of thinking, to comprehension questions, application, analysis, synthesis, and evaluation. Later, Anderson and Krathwohl (2001) changed the taxonomy by emphasizing the differences between the cognitive processes and classified it according to memory questions...remembers, understand, apply, analyze, evaluate, and create. In another classification, a continuum from confirmation questions to transformation questions is presented. Confirmation questions are meant to clarify information, define and explain concepts, while transformation questions involve a reconstruction and reorganization of the student’s understanding (and Watts 2003 Pedrosa, Teixeira-Dias).

Students ask basic knowledge questions on topics they are less familiar with, while they can ask higher-order questions, with a much higher potential educational contribution, on topics they have a better grasp of. For the most part, students will have a hard time asking higher order questions when they are just starting learning a topic and therefore in order to ask such questions, the student should have a satisfactory grasp of the subject (Scardamalia and Bereiter 1992).

***Student question-generation***

The pedagogical value and importance of SQG is empirically well founded. A comprehensive analysis of 109 empirical studies on SQG that were conducted in numerous disciplines and across all ages (from elementary school to college), presenting widespread consensus on the positive effects on learning (Yu 2012). For example, a comprehensive study that was conducted on Science students from three different universities in Britain examined the effect of three student activities associated with multiple choice questions: solving questions, generating questions, or checking and commenting on peer questions. A significant positive correlation was found between these activities and test grades (Hardy et al. 2014). Another study found a correlation between a low order of questioning and poor student achievements (Tisher 1977).

A study of 10th grade Science pupils found that pupils that practiced question-generation improved both their questioning ability and their academic achievements. The findings also showed that question-generating skills can serve as an alternative assessment method, mainly to assess higher-order thinking (Dori and Herscovitz 1999; Offerdahl and Montplaisir, 2014). In fact, SQG can reinforce knowledge building and connect between learning and assessment (Gulikers, Bastiaens and Kirschner 2004; Papinczak et al. 2012). Medical students that practiced question-generation in their last year of studies felt more confident and exhibited more positive perceptions of their assessment methods (Baerheim and Meland 2003). Koch and Eckstine (1991) also found that college Physics students improved their reading comprehension when they were taught question-generation skills. This skill stimulated students' self-awareness of difficulties in reading comprehension and could serve as a self-assessment technique.

Question-generation is an important metacognitive strategy that focuses the student’s attention on the content and main ideas and develops critical thinking, self-criticism, and creativity (Chin and Brown, 2002; Rothstein and Santana 2011; Cuccio-Schirripa and Steiner 2000) . An interesting comparison was made between the effect of the students’ ability to answer questions and their ability to generate questions, when their academic achievements and cognitive and metacognitive strategies were examined. In contrast to the aforementioned studies, this study found no differences in the academic achievements among the students that were engaged in answering questions and those that generated questions, and both activities were equally effective. However, the students that were engaged in generating questions displayed significantly higher cognitive strategies and metacognitive skills. These students were more aware of their learning process, were more self-critical and able to self assess their progress, and willing to change (Yu and Liu 2008).

Numerous studies point to the dramatic effect the social aspect has on the nature of learning and thinking (like: Howe1996; O’Loughlin 1992; Hennessy 1993) and therefore question-generation in a group may be an even more meaningful cognitive activity than generating questions individually. The discussion among the pupils during the activity stimulates the distinction in the various perspectives and possibilities, and develops the ability to reason and think critically (Chin and Osborne 2008). But there are also findings that point to the complexity in producing the advantages of cooperative learning. For example, in a study conducted on medical students that worked in groups to generate questions for their tests, the researchers found that cooperative learning did not improve the ability to generate questions and did not influence their learning habits (Jobs et al. 2013).

Despite SQG’s value in promoting learning, this activity is hardly incorporated in learning. Numerous lessons tend to be teacher-controlled monologues. The students in the class ask few questions (Nystrand et al 2003), and when they do ask, the majority of questions are basic knowledge questions requiring regurgitation of the information and not in-depth understanding questions (Chin and Brown 2002; Dillon1988; Middlecamp and Nickel 2005). Particularly in higher education, the students’ focus is on questions that the teachers ask or that are taken from textbooks. Independently formulating questions, mainly those involving higher order thinking, is a process that pupils practice at a very limited scope (Dori and Herscovitz 1999; Yu and Chen 2014).

Several reasons were proposed for students’ limited question-generation experience. Teachers that do not feel confident enough in their discipline will suppress questioning. Or teachers that studied the topics they teach via a didactic approach based on frontal teaching will teach this way themselves and not encourage pupils to ask questions (Woodward, 1992). When the teacher constantly controls questioning in a lesson it encourages the pupils to be passive (Good et al. 1987). Also the atmosphere in the class, the pupils’ fear of a negative response, and teacher-pupil relations will influence the pupils’ questioning (Dillon 1988). The number and type of questions the pupils ask depends on numerous additional factors, such as the pupils’ age, their experience, skills, nature of the studied subject and interest in it, and degree of proficiency in the material (Shodell 1995).

As stated, several studies have dealt with ways in which the teachers ask questions, however there are far fewer systematic studies about SQG. The current study examines the effect of question-generation by Science Education students after they have learned topics in cell biology and have attained a certain proficiency in the material. The purpose of the study was to clarify whether the students will improve their achievements and their cognitive capabilities after a group question-generating exercise, and solving and assessing their peers’ questions. Another goal was to examine whether the experience affected other aspects, such as cooperative learning, increasing self-confidence, reducing test anxiety, and so forth. These goals led to the following research questions:

1. Did the practice of students generating, solving, and assessing questions improve the course’s final exam grades?
2. Did the practice of generating questions at higher order thinking and solving them improve the ability to cope with such questions in the exam?
3. What are the students’ opinions on generating, solving, and assessing questions? Did it contribute? If yes, in what way? If no, then why not?

**Methodology**

***The Research Approach***

The research is based on comparative pre / post-test intervention. The intervention refers to the students engaging in generating, solving, and peer assessment of questions in a college cell biology course.

***Participants***

The research population included six classes of Science Education students that were taking a cell biology course, in two academic education colleges in Israel. The two colleges are located in the South of Israel, are attended mainly by females, and their Science Education curricula are very similar. A total of 133 students participated in the study (118 women and 15 men), with an average age of 22.3 years. The number of students in each class is detailed in Table 1. All the students studied the same course syllabus with the same lecturer, who had around 20 years of experience.

***The Research Process***

The study was conducted over four academic years, between the years 2010 and 2014. The Cellular Biology course was taught in each of the six classes for two semesters, one semester from October to January and the second semester from March to June. The lessons for each course were given once a week for two hours, for a total of 56 hours per course, 14 lessons per semester. In the 1st semester, the students did not engage in question-generation. In the last lesson of the 1st semester, time was set aside to review for the exam and the students were given examples of questions and also an opportunity to ask questions on each of the topics studied during the semester. In the 2nd semester, the students engaged in question-generation and the activities were conducted according to the following breakdown:

1. In the 5th lesson of the 2nd semester, the students were presented with examples of questions at various orders of thinking on a topic that had already been covered - the passage of substances through the cell membrane. The students were already familiar with the concepts pertaining to the types of questions and Bloom’s taxonomy from the education courses. However, the students did not have much experience with classifying questions. In order to simplify matters, a general classification into two groups of questions was demonstrated, the first were basic knowledge questions and memorization, and the second group of questions were at higher orders of thinking and included all the other types of questions, like comprehension, application, and synthesis questions. The activity lasted around 30 minutes and at the end, the students were given a homework assignment to be completed in pairs. The exercise, which was defined as one of the student requirements in the course, included generating three questions about substances passing through the cell membrane, at least two of which were questions from the second group, like comprehension or application questions. The students were required to upload the questions to the course website within a week and also to solve and comment on another pair’s questions.
2. In the 7th lesson, examples of student questions were presented in class and a discussion was conducted on the questions’ level, clarity, and solutions. The class activity lasted around 40 minutes. Some of the students reported difficulty in generating questions, mainly higher order thinking questions, and the length of time they spent on the exercise.
3. The final lesson of the 2nd semester was entirely devoted to generating and solving questions by the students. At the beginning of the lesson it was stressed to the students that the activities in the lesson would help them summarize and organize the material and would result in building a question bank to help them review for the exam. Moreover, the sequence and manner of activities as they are detailed below was briefly explained in advance:

* The teacher divided the class into 4-5 groups of 3-4 students, depending on the size of the class. Each group was heterogeneous with regards to their achievements in the 1st semester and included students that received a high grade in the 1st semester and students with mediocre or poor grades.
* Each group was given one main topic from among the topics studied during the 2nd semester and was asked to generate 5 questions about their topic, at least 3 of which were higher order thinking. Forty minutes were allocated for the question generation and the pupils used the materials from the lectures, the course website, digital books, and various websites to help them with the assignment.
* During the student question-generation, the groups were guided by the lecturer, who mostly helped with the complex question generation, and encouraged the less active students to participate. The group uploaded the questions to the course website after the lecturer gave her approval.
* When the 40 minutes of question generation were up, each group received another group’s questions, solved them for around 30 minutes, and then commented on their level, how they were phrased, and so forth. The answers and the comments were given to the group that generated the questions.
* When the activity was over, a bank of around 25 questions on all of the course topics in the 2nd semester was created on the course website, 60% of which were higher order thinking questions.

To summarize, the sequence of the question-generation and solving activities was as follows:

1. A class discussion on the types of questions and their classification. 2. A homework assignment to generate and solve questions. 3. A class discussion on the homework assignment. 4. A group activity in class to generate and solve questions. 5. Creating a question bank.

***Data Sources***

In order to examine the effect of SQG, the following sources were used:

1. Exams - At the end of each semester, the students were tested on the topics covered during the semester. Each exam included around 15 questions, the majority of which (around 11) were closed questions involving knowledge and memory, and four questions (around 25% of the exam) were open questions that tested comprehension, application or synthesis. The exams were very similar for all six groups, with minor variations.
2. Questionnaire - The students from classes 4, 5, and 6, a total of 57 students, were asked to answer the following question in writing: “Did you benefit from engaging in question generation coupled with solving and assessing questions? If yes, in what way? If no, then why not? Explain and elaborate as much as possible”. The students answered the question in the last lesson of the 2nd semester, at the end of the activity, for around 15 minutes.

***Data Analysis***

1. The student exams in the 1st and 2nd semesters were graded and the averages and standard deviations of each group’s grades and of all the groups’ grades were calculated. The four higher order thinking questions were graded using a uniform gauge according to which points were given for the accuracy of the answers, a description of the explanation, and the reasoning. The average grade and standard deviations for the thinking questions of each student, each group, and all the groups overall were calculated. Thirty out of 133 exams (5 exams from each group) were graded by an additional lecturer with extensive experience in cell biology. The correlation between the grades was high, at 89%. For a comparison between 1st semester and 2nd semester grades for each student, paired t-tests between the overall grades of the exams in each semester and also between the grades for only the thinking questions were conducted. In addition, an Anova test was conducted to examine the differences between the groups’ grades. No significant differences were found between the groups with regards to the overall exam grades in each semester and also with regards to the grades for the thinking questions, and therefore all the students can be treated as one group.
2. The answers of the 57 students to the question pertaining to the benefit of engaging in question-generation generally included more than one statement. A total of 110 statements were obtained. The responses underwent a content analysis (Marshall and Rossman 2011) and divided into categories that were constructed according to the content of the statements. The categories were determined separately by two researchers.

Inter-rater reliability checks were conducted between the researchers to check for consistency.

Several differences were found between the two analyses and after a joint discussion a consensus was reached to divide the students’ statements into six categories. The categories detailed in Table 3 include, for example, reference to the question bank, to the skill of question-generation, or to cooperative learning. The percentage of students that stated the category and percentages of each category of all the statements were calculated.

**Findings**

***A Comparison of Exam Grades Before and After SQG***

Table 1 presents the comparison between each class’s exam grades in the 1st semester, before SQG and the 2nd semester grades after SQG. Once can see that there was no statistically significant increase in exam grades in most classes after engaging in question-generation. Only in two of six classes there was a statistically significant rise in grades after engaging in question-generation. Also, a calculation of all the students found that engaging in question-generation did not affect the overall exam grade.

*Place Table 1 here.*

***A Comparison between the Thinking Question Grades Before and After SQG***

A comparison between only the thinking question grades on the exam before and after SQG presents a different picture than a comparison of the overall exam grade. As Table 2 shows, an examination of all the students shows that there is a statistically significant rise in the thinking question grades after the students engaged in question-generation. However, this rise was not exhibited in all the classes. In fact, only in three of the six classes there was a statistically significant rise in grades after engaging in question-generation.

*Place Table 2 here.*

***The Benefit of SQG***

The students’ responses regarding the benefit of engaging in question-generation, divided into six categories, is summarized in Table 3. The statements on the benefit of the question bank generated by the exercise were the most prominent, over 70% of the students wrote about the importance of the question bank in reviewing for the exam. Twenty percent of the students also stated that generating the questions reduced their test anxiety. Around one third of the students addressed the skills they acquired, such as formulating questions and checking and assessing the answers, skills that were important to them as future teachers. Twenty eight percent of the students wrote statements about being better equipped to cope with thinking questions and around a quarter of the students stated the benefit of the group work and the enjoyment from cooperative learning. In contrast to them, around 16% of the students wrote that they did not benefit from the exercise, which they claimed was too short or too difficult.

*Place Table 3 here.*

**Discussion**

An analysis of the findings shows that the students’ engagement in question-generation did not significantly improve most of the students’ exam grades. However, two of the six classes exhibited an improvement in the exam grades, however, the fact the there was no statistically significant rise in grades in four of the classes after the question-generation activity reinforces the hypothesis that the improvement in the two classes was not related to question-generation. These findings seemingly contradict other empirical studies that showed that SQG contributes to academic achievements (Yu 2012). However, a more in-depth analysis referring to student achievements in only the thinking questions (comprising only 25% of the overall exam grade), presents a different picture.

An analysis of all the students indicates that the achievements in solving thinking problems after engaging in question-generation resulted in a statistically significant increase. From here it seems that after a relatively brief exercise in question-generation, the students’ cognitive abilities improved. Similarly, Yu and Liu’s study (2008) found that college students that engaged in question-generation exhibited significantly higher cognitive strategies. It is interesting to note that when the students in the current study were asked about how the question-generation exercise benefitted them, some hoped that formulating thinking questions would improve their ability to cope with thinking questions. The students wrote their opinions down before they took the 2nd semester exam, and indeed the thinking question grades improved. It is important to emphasize that the students composed questions once they were familiar with the topics. The degree of proficiency in the material had a direct effect on the type and level of the questions (Scodell 1995) and the students in the current study were given the required knowledge foundation to formulate higher order thinking questions.

The SQG activity in this study is conducted in pairs (the homework exercise) or in groups (class exercise). The beneficial effect of cooperative learning on thinking, reasoning, and the nature of learning has been known for some time (O’Loughlin 1992; Hennessy 1993; Chin and Osborne 2008; Hsiung 2012). It can be presumed that the discussion between the students during the question-generating activity, the sharing of knowledge and the need to hone and clarify matters contributed to more in-depth thinking about the topics, which led to an improved coping with the thinking questions. Some of the students also wrote explicitly about the contribution of group learning to the question generation and the peer assessment and to their enjoyment from the cooperative learning.

Despite these encouraging findings, they must be treated cautiously An analysis of each class’s achievements in the thinking questions found that there was not a statistically significant improvement in the thinking question grades after the question-generation exercise for all the classes. Although statistically no differences were found between the groups and all six classes can be addressed as one group, it is important not to overlook the fact that for three classes there was no improvement in the thinking question grades. Also the relatively high value of the standard deviations of the thinking question achievement averages highlights the significant differences between students.

Undoubtedly, a different social environment and dynamic develops in the different classes, which influences the individual's learning. Furthermore, it can be presumed that the group activity is not effective for students that have a hard time cooperating or those that prefer to study alone. Students are differentiated by their learning approaches, degree of interest, ability to take risks or cope with uncertainty (Pedrosa, Teixeira-Dias and Watts 2003). All these may affect their flexibility to change learning strategy and to engage in tasks that they were not accustomed to, such as question-generation. Another option is that the duration of the exercise (less than three hours in class and one homework assignment) was too short for some of the students. As stated, generating questions, unlike solving questions, is a new and fairly difficult exercise for most students and some require more time, encouragement, and support (Chin and Brown 2002).

From an analysis of the students’ opinions on the entire exercise of formulating, solving, and peer assessment of questions, the practical aspect of the question bank’s advantage for reviewing for the exam was the most prominent. Without a doubt, knowing that the activity would lead to building a shared review question bank was the students’ main motivator. It was expected that the students, who aspired to succeed in the exam and were very focused on this goal, would readily engage in an activity that could potentially benefit their goal directly. A similar study was conducted on medical students that worked in small groups to build a question bank while also checking and assessing their peers questions. The study showed that 91% of the students believed that the bank had significant value in reviewing for the exam and they expressed a desire to build such banks in the future as well (Gooi and Sommerfeld 2015).

However, in another study on medical students that engaged in a group activity of question-generation, Papinczak et al (2012) showed that the question bank the students built did not contribute to in-depth learning. The students were promised that 25% of the exam questions would be composed of the questions they would formulate and they chose mainly to memorize the questions and answers. In contrast, in the current study, the students were not promised that their exam would contain questions from the bank they built, although it was stressed that some of the exam questions may be similar. Perhaps this adversely affected some of the students’ motivation to generate questions but it may have also prevented them from adopting superficial learning tactics.

The majority of students in this study, who had not previously engaged in systematic question-generation, were surprised to discover how difficult the assignment was. In some of the students’ opinion, the exercise helped to improve their question-generating and assessment skills, but as future teachers they asked to continue to strengthen these skills. The students had virtually no experience in peer-assessment and giving feedback on their peers’ questions. The empirical evidence on the contribution of peer assessment is sizeable and indicates that it promotes critical thinking, cognitive development, and performance (Nelson and Schunn 2009; Topping 2010; van Gennip, Segers and Tillema 2010). Yu & Wu (2016) recently showed that students that give quality feedback to their peers’ questions tend to generate higher quality questions. In addition to promoting cognitive abilities, the question generation in this study, coupled with the peer assessment, encouraged the students to reflect on the questions they composed and on their learning in general.

***Limitations of the Study***

One of the study’s limitations is that the comparison between each student’s 1st semester grade (the control - prior to SQG) and the 2nd semester grade (the experiment - after SQG) was conducted on different topics that were studied during each semester. Various topics, even they belonged to the same discipline, may affect the degree of comprehension and the ability to cope with the exam questions. However, the alternative of a comparison between different students that study the same topics would have created a more significant research limitation due to the variance among the students.

Additional limitations were the relatively brief time of engaging in question-generation and the relatively small number of students that answered the open question (only 57). It can be presumed that a more prolonged and thorough engagement would have led to a more inclusive improvement in the students’ grades. In addition, had all 133 students answered the open question, perhaps a different picture would have been obtained regarding their opinion of question generation.

Another general limitation is related to the study’s characteristics. In every study based on a researcher researching his work and involved in the research process, it is difficult to claim maximum objectivity. In the current study the researcher taught the students that participated in the study, and conducted the activities.

**Conclusions and Recommendations**

1. The current study showed that even a relatively brief engagement in generating comprehension and application questions by the students improved their ability to cope with these types of questions in the same discipline. Furthermore, SQG presents additional advantages, such as reducing test anxiety, acquiring skills in formulating questions or productive group learning. The main conclusion from these encouraging findings and also from other researchers’ findings is that SQG should be adopted as a built-in and more dominant activity in the curriculum.
2. In order to encourage students to generate questions, teachers, the majority of whom were accustomed to teaching as they were taught, need to be trained accordingly. The teachers must challenge the students to question and to stimulate their motivation in setting goals such as building a review question bank for an exam. It is also important that the students become familiar with the taxonomy of questions. Different types of questions on various topics must be demonstrated, and class time must be allocated to formulate questions and give homework that will include question-generation.
3. It is recommended that the students’ engagement in formulating questions at higher thinking orders after at least a basic competence in the material is achieved. Some of the students in the current study had difficulty formulating even simple knowledge questions, all the more so higher order thinking questions, due to inadequate mastery of the material.
4. It is highly recommended that students are allowed to generate questions in groups and solve and assess their peers’ questions. The interaction and the cooperative learning impart significantly valuable cognitive and metacognitive advantages. Generating questions forces the students to master the material and the peer assessment stimulates reflection on the individual learning.
5. Students’ ability to generate questions may serve as a means to assess higher-order thinking, as shown by Dori and Herscovitz (1999) for example, and therefore question-generation has the potential to serve as an alternative assessment tool and as an alternative to conventional assessment methods.

In summary, SQG is a constructive strategy of active learning with valuable potential. The current study offers teachers working in higher education settings a potential model to incorporate SQG in their teaching. The more teachers incorporate self generation and peer assessment of questions, and do not suffice with simply answering questions, the more they will promote learning where the students are more active, involved, and in charge of their learning.

**References**

Anderson, L.W., and D.R. Krathwohl. 2001. *A taxonomy for learning, teaching, and assessing: A revision of Bloom’s taxonomy of educational objectives*. New York: Longman

Baerheim, A., and E. Meland. 2003. Medical students proposing questions for their own written final examination: Evaluation of an educational project. *Medical Education* 37 (8): 734–738.

Biddulph, F., D. Symington, and R. Osborne. 1986. The place of children’s questions in primary science education. *Research in Science and Technological Education* (4): 77–88.

Bloom, B.S., M.B., Engelhart, E.J., Furst, W.H., Hill, and D.R. Krathwohl. 1956. *Taxonomy of educational objectives: The classification of educational goals* (Handbook 1: Cognitive domain). New York: Longmans Green.

Chin, C., and D.E. Brown. 2002. Student-Generated Questions: A Meaningful Aspect of Learning in Science. *International Journal of Science Education* (24): 521–549.

Chin, C., and G. Kayalvizhi. 2005. What do pupils think of open science investigations? A study of Singaporean primary 6 pupils. *Educational Research* 47(1): 107–126.

Chin, C., and J. Osborne. 2008. Students' questions: a potential resource for teaching and learning science. *Studies in Science Education* 44 (1): 1–39.

Cuccio-Schirripa, S., and H. E., Steiner. 2000. Enhancement and analysis of science question level for middle school students. *Journal of Research in Science Teaching* 37(2): 210–224.

Dillon, J.T.1988. The Remedial Status of Student Questioning. Journal of Curriculum Studies (20):197–210.

Dori, Y. J., and O. Herscovitz. 1999. Question-posing capability as an alternative evaluation method: analysis of an environmental case study. *Journal of Research in Science Teaching* (36): 411–430.

Furtak, E.M., and M.A. Ruiz-Primo. 2008. Making students’ thinking explicit in writing and discussion: an analysis of formative assessment prompts. *Science Education* (92): 799–824.

Gulikers, J., T. Bastiaens, and P. Kirschner. 2004. A five-dimensional framework for authentic assessment. *Educational Technology Research and Development* 52(3): 67–76.

Good, T. T., R. L., Slavins, K. H., Hobson, and H. Emerson. 1987. Student passivity: a study of question asking in K-12 classrooms. *Sociology of Education* (60): 181–199.

Gooi, A. C. C., and C. S. Sommerfeld. 2015. Medical school 2.0: How we developed a student-generated question bank using small group learning. *Medical Teacher* 37(10): 892. Retrieved from https://search.proquest.com/docview/1720983690?accountid=41238

Hardy, J., S. P., Bates, M. M., Casey, K. W., Galloway, R. K., Galloway, A. E., Kay et al. 2014. Student-generated content: Enhancing learning through sharing multiple-choice questions. *International Journal of Science Education* 36(13): 2180-2194.

Hennessy, S. 1993. Situated cognition and cognitive apprenticeship: Implications for classroom learning. *Studies in Science Education* 22: 1–41.

Howe, A. 1996. Development of science concepts within a Vygotskian framework. *Science Education* 80(1): 35–51.

Hsiung, C. M. 2012. The effectiveness of cooperative learning. *Journal of Engineering Education* 101(1): 119–137.

Jobs, A., Twesten, C., Göbel, A., Bonnemeier, H., Lehnert, H., and G. Weitz. 2013. Question-writing as a learning tool for students – outcomes from curricular exams.

*BMC Medical Education* 13: 89.

Koch, A., and S. G. Eckstein. 1991. Improvement of reading comprehension of physics texts by students’ question formulation. *International Journal of Science Education* (13): 473–485.

Marshall, C., and G. B. Rossman. 2011. *Designing qualitative research* (5th ed.). Thousand Oaks, CA: Sage.

Mason, M. 2007. Critical Thinking and Learning. *Educational Philosophy and Theory* 39 (4): 339-349.

Middlecamp, C.H., and A. L. Nickel. 2005. Doing Science and Asking Questions II: An Exercise That Generates Questions. *Journal of Chemical Education* 82(8):1181–1186.

Nelson, M. M., and C. D. Schunn. 2009. The Nature of feedback: How different types of peer feedback affect writing performance. *Instructional Science* 37(4): 375–401.

Nystrand, M., Wu, L. L., Gamoran, A., Zeiser, S., and D. A. Long. 2003. Questions in time: Investigating the structure and dynamics of unfolding classroom discourse. *Discourse Processes* 35(2):135–198.

Offerdahl, E. G., and L. Montplaisir. 2014. Student Generated Reading Questions: Diagnosing Student Thinking with Diverse Formative Assessments. *Biochemistry and Molecular Biology Education* 42(1):29–38.

O’Loughlin, M. 1992. Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching* 29(8): 791–820.

Pedrosa, D. J., H., Teixeira-Dias, J.J.C., and M. Watts. 2003. Questions of chemistry. *International Journal of Science Education* 25(8): 1015–1034.

Rothstein, D., and L. Santana. 2011. Make Just One Change: Teach Students to Ask Their Own Questions. Harvard: Harvard Education Press.

Scardamalia, M., and C. Bereiter. 1992. Text-based and knowledge-based questioning by children. *Cognition and Instruction* 9:177–199.

Shodell, M. 1995. The question-driven classroom. *The American Biology Teacher* 57:278–281.

Tisher, R. P. 1977. Practical insights gained from Australian research on teaching.

*Australian Science Teachers Journal* 23: 99–104.

Topping, K. 2010. Methodological quandaries in studying process and outcomes in peer assessment. *Learning and Instruction* 20: 339–343.

Papinczak, T., R. Peterson, A. S. Babri, K. Ward, V. Kippers and D. Wilkinson. 2012. Using student-generated questions for student-centred assessment. *Assessment & Evaluation in Higher Education* 37(4):439–452.

van Gennip, N. A. E., Segers, M., and H. H. Tillema. 2010. Peer assessment as a collaborative learning activity: The Role of interpersonal variables and conceptions. *Learning and Instruction* 20(4): 280–290.

Watts, M., and S. Alsop. 1995. Questioning and conceptual understanding: the quality of pupils’ questions in science. *School Science Review* 76(277): 91–95.

Watts, M., G. Gould, and S. Alsop. 1997. Questions of understanding: categorising

pupils’ questions in science. *School Science Review* 79(286): 57–63.

Woodward, C. 1992. Raising and answering questions in primary science: some considerations. *Evaluation and Research in Education* 6: 145–153.

Yu, F.Y. 2012. Learner-centered pedagogy + adaptable and scaffolded learning space design-Online student question-generation. In *International conference on computers in education* (pp. 26-30). Singapore.

Yu, F. Y., and C. P. Wu. 2016. Predictive Effects of the Quality of Online Peer-Feedback Provided and Received on Primary School Students’ Quality of Question-Generation. *Educational Technology & Society* 19 (3): 234–246.

Yu, F.Y., and Y.H. Liu. 2008. The comparative effects of student question-posing and question-answering strategies on promoting college students' academic achievement, cognitive and metacognitive strategies use. *Journal of Educational Psychology* 31(3):25–52.

Yu, F.Y., and Y.J. Chen. 2014. Effects of student-generated questions as the source of online drill-and-practice activities on learning. *British Journal of Educational Technology* 45 (2): 316-329.

Zoller, U., G. Tsaparlis, M. Fatsow, and A. Lubezky. 1997. Student self-assessment of higher-order cognitive skills in college science teaching. *Journal of College Science Teaching* 27*:* 99–101.

Table 1. A comparison between the students’ overall test grades before and after SQG

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *p* | *df* | *t* | Overall grade after SQG (SD) | Overall grade before SQG (SD) | No.  of students | Class |
| .52 | 24 | .65 | 74.44  (14.05) | 73.36  (17.52) | 25 | 1 |
| .02\* | 24 | 2.50 | 74.72  (17.99) | 71.28  (16.84) | 25 | 2 |
| .04\* | 25 | 2.22 | 72.12  (16.98) | 68.04  (18.72) | 26 | 3 |
| .29 | 26 | 1.07 | 71.93  (14.57) | 74.26  (14.58) | 27 | 4 |
| .46 | 14 | .76 | 72.93  (12.71) | 70.93  (16.04) | 15 | 5 |
| .93 | 14 | .09 | 73.93  (15.42) | 74.13  (18.16) | 15 | 6 |
| .09 | 132 | 1.71 | 73.30  (15.32) | 71.92  (16.82) | 133 | Total |

Table 2. A comparison between the thinking question grades before and after SQG

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *p* | *df* | *t* | Grade after SQG (SD) | Grade before SQG (SD) | No.  of students | Class |
| .52 | 24 | 1.08 | 62.60  (28.87) | 57.80  (30.75) | 25 | 1 |
| .00\*\* | 24 | 5.39 | 62.40  (30.62) | 39.00  (28.02) | 25 | 2 |
| .02\* | 25 | 2.48 | 64.42  (26.62) | 52.88  (29.43) | 26 | 3 |
| .40 | 26 | .85 | 61.85  (24.30) | 58.15  (25.84) | 27 | 4 |
| .00\*\* | 14 | 3.71 | 65.33  (29.43) | 43.33  (19.97) | 15 | 5 |
| .29 | 14 | 1.09 | 60.00  (22.76) | 51.67  (29.07) | 15 | 6 |
| .00\*\* | 132 | 5.56 | 62.78  (26.86) | 51.05  (28.23) | 133 | Total |

Table 3. The students’ opinions on practicing question-generation

|  |  |  |  |
| --- | --- | --- | --- |
| Selected student statements | % of  Statements n= 110 | % of Students n= 57 | Category |
| ‘The question bank made it easier for me to prepare for the exam’; ‘I was mostly happy with the question bank because I could review them before the exam’; ‘The question bank was the most beneficial. I wish it was possible to build a bank like this in other courses’ | 38.18 | 42 73.7 | Preparing for the exam - question bank |
| ‘This experience is really important for me as a future teacher who will be compiling tests. This is the first time I did this’; ‘When we tried to generate higher order thinking questions, it was hard. At first we generated a lot of closed and relatively simple questions... but this is how we acquired tools to generate all sorts of questions’ | 13.64 | 18 31.58 | Question generating and assessment skills |
| ‘I hope that writing and solving complex questions will help me cope with these types of questions in the exam’; ‘The exercise helped me better understand open questions’ | 14.54 | 16 28.0 | Coping with higher order thinking questions |
| ‘I enjoyed the group work in class, mainly in the last lesson, there was a great atmosphere’; ‘My group was strong and we managed to generate nice questions’ | 15.45 | 14 25.56 | Cooperative learning |
| ‘I hope that I will be less anxious of the 2nd semester exam because of the exercise and the question bank’; ‘The question writing exercise was important for me because I really suffer from test anxiety...’ | 10.90 | 12 21.0 | Test anxiety |
| ‘I prefer answering questions to generating questions... It’s what I’ve been accustomed to’; ‘Engaging in question writing was good but too brief and I don’t feel that it helped me much’; ‘I had a hard time generating higher order thinking questions. Even generating closed questions was complex...’ | 2.8 | 7 15.8 | Did not contribute much |