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The Characteristics of Students Engaged in Spontaneous Problem-Posing

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Abstract: Spontaneous problem posing is a basic concept of spontaneous mathematical thinking and science learning. Students generate problems without systematic encouragement and pose problems based on the student's desire to develop their skills. As a result, they can serve as important markers of constructive mathematical and science engagement, particularly affective engagement, for problem solvers and their classroom communities. We used a qualitative approach to analyze student characteristics, especially in the affective domain, when presenting random problems. We used an observational approach and experience sampling in each class to observe students' engagement in spontaneous problem posing both individually and in groups. The findings revealed that each student showed different characteristics when presenting problems suddenly (spontaneous problem posing). The submission of the first subject problem was categorized as problem-as-exercise, satisfying the characteristics of spontaneous originality, where constructive emotional experiences impressed more on the teacher, while negative emotional experiences impressed more on oneself (self), classmates, and mathematical activities. The submission of the second subject problem is classified as a problematic problem, fulfilling the characteristics of spontaneous originality. Negative emotional experiences are more visible in me (myself), while constructive emotional experiences are more visible in teachers, classmates, and math activities.

Keywords: Originality Spontaneous; Problems-as-problematic; Problem-as-exercise; Spontaneous problem-posing

Introduction

For the past three decades, researchers in the field of mathematics and science education have investigated issues that occur in the critical mathematical practices of students, with the aim of both developing students' intellectual awareness and engaging students in the exploration of mathematical concepts (Cai et al., 2013; Carrillo & Cruz, 2016; Harpen & Presmeg, 2013; Singer et al., 2015). Previous research has also offered significant insight into how students pose problems themselves (problem posing) for students to formulate and improve their mathematical reasoning and science (Cai, 2003; Kontorovich et al., 2012; Rosli et al., 2014) however, literature on spontaneous problem-solving is only in its early stages.

Past studies have suggested that unexpected student inquiries, which could include teacher-posted challenges, are indicative of a fruitful relationship with mathematics and science, and have a positive impact on pupils (Chin & Osborne, 2008; Sengupta-Irving & Enyedy, 2015). Research has also shown that students should pose challenges, should not hurry through the problem-solving process, and re-examine the issues that occur during the solution (Cifarelli & Sevim, 2015) uncovered proof of measurable beneficial outcomes, such as excitement and involvement in tough problems. We will investigate spontaneous problem-posing by

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students during the learning process in this report. The phenomenon of students asking their questions without being asked is known as spontaneous problem-posing.

According to Schoenfeld (2016), who addresses mathematical thinking, science and problem-solving, problems are described in the literature in two fundamentally different ways: as exercises or reviews of procedural techniques; and as a way to articulate questions that are considered difficult to answer. Schoenfeld distinguishes between problems as routine exercises (problems-as-exercises) and "problems" as problematic situations (problems-as-problematic). Even though Schoenfeld's papers were written almost 30 years ago, his comments remain a reasonably reliable characterization of the kinds of challenges students frequently encounter in the classroom, as well as the types of problems teachers plan to teach their students (Çakır & Akkoç, 2020; Jr & Cai, 2016; Reiss & Törner, 2007). Most students continue to use conventional problem-solving methods, including problem-solving to acquire, employ, and update current techniques and procedures.

That problems-as-exercises were used to assess rather than construct mathematical thinking science, the mathematics education community was reminded at the time that problems-as-problematic situations was the basis or foundation for achieving a more meaningful mathematics learning experience. Additionally, Schoenfeld highlights the importance of issues in defining and describing patterns of observable regularities empirically and intellectually. The problems given might be classified as problems-as-exercises or problems-as-problematic situations, based on the problems' description and the type of software used by students and professors to pose the problems (Fonteles et al., 2019). Experts in psychology and creativity classify different types of problems based on the description of the problems, known as epistemic source, and the motivation of the individual who raises the problem, known as epistemic motivation. A more general literature review distinguishes three categories of problems, namely presented, discovered, and created problems, which differentiate between the student as the poser (discovered and created problems) and teachers or other external influences as the poser (presented problems) (Getzels & J.W., 1979). The type of problem most often used in mathematics learning at school is the problem posed by the teacher, which belongs to one of the three types of problems mentioned previously. Typically, the instructor or expert already knows the answer and expects the problem to be solved by others, such as pupils. Such problems are usually identical to problems-as-exercises, in which the focus is on practicing a skill.

Spontaneous problem posing in this study fulfills the characteristics: there is no external desire to pose a problem (it occurs randomly on the prompting of students), and problem-posing is performed by students and has never been encountered before (spontaneous originality). In the learning environment, Leikin & Pitta-Pantazi (2013) describe originality as something unique, unexpected, or uncommon. Researchers describe originality as a concept that was previously unknown to students, whether it was an idea to solve or create a problem.

Method

One hundred and two science students and two mathematics teachers from one of Makassar's public junior high schools took part in this study. Individual problem posers' activities and relationships with their instructor are represented using video-recorded classroom episodes. Then, for each lesson, we aggregate all of the students' self-reported affective experiences. Our data came from video-recorded classroom evaluations and surveys using the experience sampling tool. Observations were mainly based on whole-class experiences and, on occasion, interactions between particular classes of students. A lapel microphone was used for the instructor, and a boundary microphone was located for a separate group of students, normally in the middle of the classroom.

The episodes were captured during a particular activity selected by the instructor as having the ability to encourage students' constructive participation. Teachers defined these activities for several purposes, including mathematical small-group teamwork, activities that could test students' reasoning limits, and activities that could enable students to explore an idea or an insight through technology or a game. Surveys using the experience sampling tool were conducted directly after the intended operation, which lasted between 20 and 40 minutes. To evaluate episode characteristics, we selected two episodes for each teacher: one with spontaneous problem-posing (SPP) and one with no signs of SPP.

To ensure comparability of teacher, students, and mathematical and science subject, episodes were matched by class time. We began by looking at cases in which a student verbalized a mathematical problem without being asked. We then reported that the students participating in the episode had decided to participate in the analysis. Following this test, we decided if the student's verbalization constituted an effort to expand their mathematical and science expertise to create a proof of originality (Aguillon et al., 2020). Such cases, along with any discourse associated with them, were classified as instances of spontaneous problem-posing, and the incident was held for further study. We then looked at videos from the same teacher and class time on various days to find parallel episodes in which the problem poser from the spontaneous problem-posing episode was present but none of the students in the episode posed a problem. We chose four teachers' paired pairs of episodes that met our standards. For the sake of brevity, we identified two symbolic situations to explain the actions and effects of particular problem posers.

Table 1. Identification of the affective domain influencing students' spontaneous problem-posing

Emotional experience quantified	Prevalence	Items
Negative emotions toward the teacher/classmates (10 items)	145	Desperate/towards my classmate (puC) Irritated/by classmate(maC) Desperate/by my teacher(puT) Embarrassed/by classmate(mlC) Dissatisfied/by classmate(keC) Agitated/by a classmate (GeC) Irritated/by my teacher(maT) Bored/towards my teacher (boT) Bored/by classmate(boC) Disappointed/by my teacher(keT)
Positive emotions toward the teacher/classmates (12 items)	179	Proud/by classmate(baC) Enthusiastic/by classmate(beC) Satisfied/by classmate(puC) Pleased/by classmate(seC) Enthusiastic/by my teacher(brT) Confident/by classmate(pdC) Optimistic /by classmate(opC) Pleased/by my teacher(seT) Proud/by my teacher(bgT) Excited/by classmate(trC) Optimistic /by my teacher(opT) Excited/by my teacher (TRT)
Negative emotions toward the math activity (6 items)	59	Disappointed/towards the math activity (keM) Irritated/by the math activity (maM) Desperate/by the math activity (puM) Embarrassed/by the math activity (mlM) Bored/by the math activity (boM) Agitated/by the math activity (geM)
Positive emotions toward the math activity (8 items)	67	Enthusiastic/towards the math activity (beM) Pleased/with the math activity (seM) Interested/in the math activity (TRM) Proud/of the math activity (bgM) Optimistic/by the math activity (opM) Satisfied/by the math activity (puM) Convinced/by the math activity (ykM) Confident/by the math activity (pdM)
Negative emotions toward the self (7 items)	130	Hesitant/towards the self (rS) Embarrassed/by myself (mlS) Desperate/by myself (puS) Irritated/by myself (maS) Agitated/by myself (guS) Disappointed/by myself (keS) Bored/by myself (boS)
Positive emotions toward the self (6 items)	60	Convinced/by myself (ykS) Satisfied/by myself (puS) Proud/by myself (bgS) Enthusiastic about/by myself (beS) Confident/by myself (pdS) Optimistic/by myself (opS)

Analysis of Problem Posers

Identifying spontaneous problem-posing and coding to describe students' spontaneous problem-posing behavior

We used descriptive coding, as defined by (Mukuka et al., 2023), to classify student actions when posing problems spontaneously, exchanging ideas with others, and acknowledging other people's ideas or opinions. We coded proof of control, which included responses such as excitement or trust, as well as associated emotions as shown by tone of voice, facial expressions, and other behaviors. At last, we recorded signs of deep thought or concentration.

The episodes were first descriptively coded by analyzing the video recording, then the transcripts, and finally going back to the video recording. The cognitive, affective, physiological, and social interaction research was used to build codes (K. H. Lee et al., 2017). We created a summary of each problem poser's effect from these codes for episodes with and without spontaneous problem-posing. The table below contains coding of the affective domain that influences students' spontaneous problem-posing during the learning process.

Result and Discussion

What are the Characteristics of Students Involved in Spontaneous Problem-Posing?

Based on the data analysis above, signs of spontaneous problem-posing during the learning process differ from one student to the next (Kontorovich, 2020; Schindler & Bakker, 2020; Voica et al., 2020). These variations are caused by differences in instructor behaviors, behavioral standards, and expectations. Even though the teacher has assigned the students into small groups during class discussions, the findings of the study suggest that students appear to pose problems spontaneously to the teacher more often than to their peers. When group discussions take place, students are more likely to demonstrate the mechanism of presenting questions to the instructor spontaneously than their peer group.

Subject 1

Subject 1 represents students who pose problem-as-exercise problems spontaneously. Problem-as-exercise is also defined as a routine problem that has a resolution procedure. The following is the problem situation the teacher gave on the first day.

Is it a rhombus? the subject inquired of the teacher. The subject considered potential problems, such as how many dots are needed to form the shape and how big is the area of the shape?. Nonetheless, the subject was reluctant to respond to any of the questions raised by the instructor. Even though the spontaneous questions asked by the subject were classified as problem-as-exercise (Carmona-Medeiro et al., 2024; Zhang et al., 2023), he assumed that he had never encountered such a shape before, so that it was certain that the subject fulfilled the characteristics of spontaneous originality. The subject understood difficult situations presented by the instructor and was challenged by them, giving rise to the opportunity to pose questions. The instructor allotted roughly one minute for the student to consider any problems that might occur in the given problem situation.

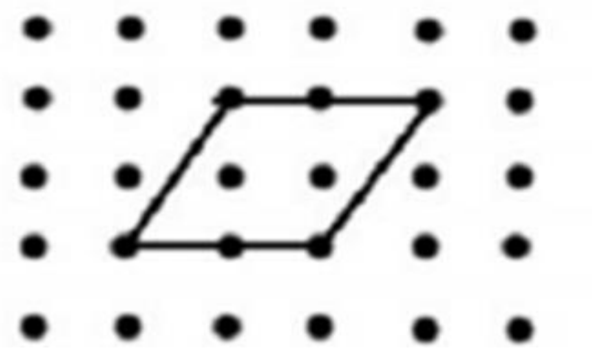

Figure 1. The instrument raises Spontaneous Problem-Posing, Source: (Rahayuningsih et al., 2021)

The instructor had previously clarified the learning goals, the learning style to be used, and the learning phases that students would have to go through. When students reached the problem-posing level, the instructor ensured that they grasped the principles of the learning so that they were able to plan questions that would be submitted within the defined content constraints. However, some students were able to parse questions outside the concept, but this is considered a phenomenon that will be revealed by digging further through interviews with the subject. The following is a transcript of the activities of the teacher and the subject observed from the video recording.

The excerpt from the video transcript above shows that the students posed questions about the pictures that the instructor showed at the center of the learning session without being directed to do so. This incident demonstrated a spontaneous problem-posing process, in which a student asked the instructor about the picture shown. However, to investigate the degree to which students' interpretation contributed to spontaneous problem-posing, the instructor asked several probing questions (J.-E. Lee & Lim, 2021). The aim was to dig deeper into each domain that the student experienced when presenting a query.

The student's problem-posing was intended to explain the area and perimeter of a two-dimensional shape. The student had an initial definition relating to two-dimensional figures (Widodo et al., 2020), so he asked for spontaneous problems. Even though the problem presented has formal steps to solve it, it suggests that the problem posed meets the characteristics of spontaneous originality, since the student described solving steps that have never been discovered. After being confirmed, the student felt he had never seen the teacher's submitted picture before. According to this explanation, the student came up with concepts that will propel class discussions in new directions in line with the learning goals devised by the instructor. As a consequence, this student satisfied the second criterion, which is spontaneous originality.

Table 2. An Example of the Spontaneous Problem-Posing Presented by Subject 1

Teacher: (The teacher shows a picture of a two-dimensional shape through visual media without directing students to respond to the picture)
Subject 1: (However, a student abruptly lifted his hand and attempted to inquire.) I have a question for you, Ma'am.
Teacher: Alright, what is it?
Subject 1: Is it a rhombus? Can I ask you how many dots make up a rhombus?
Teacher: What information would you provide with such a question?
Subject 1: I thought that by counting the dots, I could find the surface area and perimeter of the rhombus.
Teacher: What are the potential answers to your questions?
Subject 1: There are 8 dots, so the perimeter of the rhombus is 8 units, and the area is 4 units.
Teacher: Can you explain further?
Subject 1: To form a complete square from the existing dots, four dots are needed, because eight dots form a rhombus so 8: 2 = 4 is obtained, so the area is 4 units.
Teacher: Why is eight divided by two? Where did you get two from?
Subject 1: Because each side has two dots, the area of the parallelogram is 2 * 2 = 4 or 8: 2 = 4
Teacher: Are you sure about it?
Subject 1: Yes, Mam (looks excited and confident with the questions raised)

Subject 2

Subject 2 represented students who are capable of posing problems-as-problematic problems. In this case, spontaneous problem-posing was addressed to the teacher. Subject 2 was very detailed and adaptable when it comes to posing questions. Based on the transcripts of video recordings taken during class, Subject 2 was seemingly able to provide the explanations for the problem presented. Affective domains that the student showed during the process included despair, nervousness, and a little hesitation in expressing opinions. However, the encouragement of group friends was able to restore the confidence of subject 2, who initially seemed hopeless and almost chose to give up by throwing the opportunity to other group participants. The following is a transcript of the interaction between the teacher and the subject shown on camera.

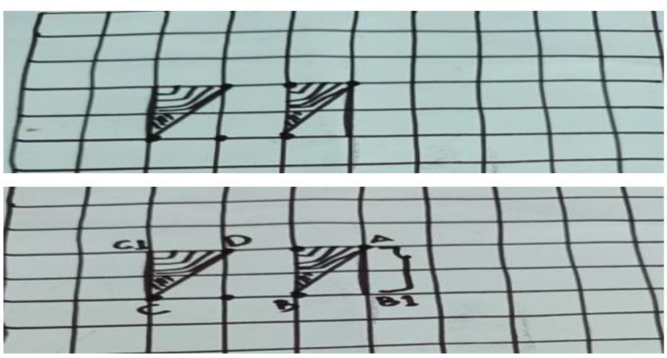

Figure 2. An Example of the Spontaneous Problem-Posing Presented by Subject 2

Table 3. An Example of the Spontaneous Problem-Posing Presented by Subject 2

(Suddenly one of the group members asked a question to the teacher)
Subject 2: can I find the area of the shape by creating several different shapes with the same area? (while drawing the illustration on the board)
Teacher: of courses and you can explain why.
(the student describes the sketch and explains it in front of the class)
Subject 2: When I drew a line connecting points A and B1 and points C and C1, I would get Figure 2.
So, the rectangle AB1CC1 was obtained,
Thus, to find the area of the ABCD shape, the area of AB1CC1 was reduced by the area of ABB1 and CC1D, which is 6 units of area minus 2 units of area = 4 units of area.
Teacher: Are you certain?
Subject 2 : (paused for a moment, and looked at his group mates) Hmm, perhaps, other group members can respond to it? (other group members acknowledged Subject 2's answer by nodding their heads and applauding him for the explanation)
Subject 2: One more thing, the next possible question might be to make a variety of shapes that have the same area. For example, a rectangle with an area of 4 units and a square with the same area.
Teacher: Can you show me the shape you're referring to?
Subject 2: Nggak suka, nggak mau Gelay,.. (a funny catchphrase for "I don't want to do it")

The student's problem-posing intended to modify the problem situation provided by the instructor, even though it is still centered on the area and perimeter of a two-dimensional figure. The questions and explanations emerged spontaneously, with little outside support (intervention from teachers and friends). This occurrence signaled the emergence of a spontaneous problem-posing process (Konopczyński & others, 2020). Since the student posed questions that other students had not thought about, the problems posed followed the criteria for spontaneous originality. The problems raised by Subject 2 are classified as problems-as-problematic since his inquiries extended beyond the acquisition of procedural expertise, stressing the need to consider the behavior of inequalities.

According to the research findings mentioned above, in general, various characteristics of students when presenting spontaneous problem-posing were exposed. The first subject's characteristics are categorized as problem-as-exercise, namely that the problem presented has a procedural solution stage, but it appears that the problem submission fulfills the characteristics of spontaneous originality, where positive emotional experience is directed at the instructor while negative emotional experience is addressed to the self, classmates, and the math activity (Headrick et al., 2020). The second subject's problem-posing traits are known as problems-as-problematic, which is more than simply learning procedural skills, but shifting the type of problems to non-routine problems (solving requires more complex thinking skills).

Negative emotional experiences appeared to be on the self and positive emotional experiences were aimed at the teacher, classmates, and math activity. This echoes research showing that students' ability to express their opinions in public is affected in part by their expectations of social encouragement, which is related to other affective variables such as self-efficacy, feelings of closeness to one another, and self-distrust (Beghetto, 2006; Bicer et al., 2020). In general, the subjects merely questioned the problems assigned to them but were unable to provide solutions. This result corroborates the view of (Schifter & Russell, 2022) mentioning that the majority of student-generated problem formulations lack a solution. Weber & Leikin (2016) reinforce their findings that students only pose routine problems without providing solutions.

Students with good academic performance can pose unusual questions, provide novel solutions, and present them. Leikin (2018) revealed that gifted students can handle difficult problems and create more mathematically challenging situations. Furthermore, research by Moses & Mohamad (2019) suggests that the problems created by students are usually more complex and unique than the problems in textbooks at their grade level. In addition, argue that it is common for gifted and talented students to produce higher-level cognitive difficulties cognitively (Aubry et al., 2021). Even though students have an active role in posing problems, they do not raise new problems in actual learning, but, they generate new problems as part of homework.

This finding is related to the expected role that students and teachers must play in problem-posing activities (Chen et al., 2015). The teacher's standards for student roles could be linked to his ideas about creating new challenges, which can take place outside of the classroom where students have ample time for learning and enjoy a peaceful learning environment. The findings also show that Problems that arise spontaneously can also be applied to science learning, such as Physics and Biology. There is a scarcity of teachers to assist students in improving the method of presenting a quality problem. The teacher is not solely concerned with motivating students to address problems. Combining problem-posing and problem-critique exercises that let students create unique, challenging, and practical challenges (Bonotto & Santo, 2015) is a pedagogical complexity. It necessitates an examination of the student's problems as well as their approach to problem-solving. This method of appraisal is connected to teachers' expectations and attitudes about problem-solving (Chen et al., 2011).

Conclusion

The spontaneously posed problems found in this analysis corresponded to one of Schoenfeld's problem characterizations. School mathematicsand science activities for first-year high school students consist mostly of problems-as-exercises, with some, but less, problems-as-problematic thrown in for good measure. The findings of the study revealed that there were different characteristics of each student when posing a problem spontaneously (spontaneous problem-posing). The characteristics of the first subject posing the problem are classified as problem-as-exercise and fulfill the characteristics of spontaneous originality. Positive emotional experiences are primarily directed at the teacher, while negative emotional experiences are primarily directed at the self, classmates, and math activity. When presenting a problem, the second subject used problems-as-problematic and satisfied the characteristics of spontaneous originality. Positive emotional experiences are geared towards the instructor (teacher), peers (classmates), math activity, science activity while negative emotional experiences are addressed to the self, math and science activity.

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and I. M. S; data curation, S. H.: writing—original draft preparation., S. R.; writing—review and editing, C. S.: visualization, S. All authors have read and approved the published version of the manuscript.

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The authors declare no conflict of interest.

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