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Does the use of differentiated instruction through project-based learning in mathematics classroom settings facilitate the students' collaborative skills?

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Abstract

This research aims to describe differentiated instruction through project-based learning on students' collaborative skills in solid geometry. This study is a case study type of research. Data collection techniques were carried out by observing and interviewing 32 students. The result of this research is that differentiated instruction begins with an assessment of student readiness and an assessment of student interest. The learning process continues with implementing three essential aspects of differentiated instruction: content, process, and product differentiation. Process differentiation begins with the implementation of project-based learning steps. In this case, differentiated teaching and project-based learning complement each other. The results of the collaborative skills show that the students in the forming category performed optimally. Pupils learn in groups voluntarily; pupils do not leave their groups, and they exchange ideas when completing their projects. However, in the other categories, i.e., students' functioning, formulating, and fermenting, they do not show maximum results.

Keywords: collaboration skills; differentiated learning; project-based learning

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Introduction

Research has shown that teaching implemented in Indonesia is currently dominated by a monotonous approach (Doli & Armiati, 2020) and dominated by the role of the teacher and conventionally practiced (Arsaythamby & Zubainur, 2014). It directly opposes the spirit of student-centered learning, which aligns with the inner demands of secondary and postsecondary students seeking personal expression and social interaction (Li & Ding, 2023). These findings also do not follow with Indonesian Government Regulation No. 57 of 2021 Chapter 1, article 1 concerning National Education Standards, which states that "Education is a planned effort to create a learning atmosphere and learning process so that students can realize their potential to have spiritual strength, self-control, character, intelligence, dignity, and skills needed for himself, society, nation and state" (President of the Republic of Indonesia, 2021). In short, education is pursued with carefully planned efforts to carry out goal-oriented learning activities that facilitate students' needs. Students can develop their skills according to their interests, readiness, and learning profile. This problem requires an appropriate teaching solution. Differentiated instruction can be used to answer students' needs to develop their skills according to their interests, readiness, and learning profile (Konstantinou-Katzi et al., 2013). In a time of shifting paradigms from teacher-centered approaches toward more student-centered approaches, differentiated instruction has become one of the leading pedagogical strategies to address individual learning needs (Aliyeva, 2021).

Tomlinson (2017) stated that differentiated instruction is a learning approach that can help students learn according to their skills, interests, and needs. Herwina (2021) also explained that differentiated instruction allows teachers to adjust classroom learning according to students' diverse needs, interests, learning readiness, and learning styles. Additionally, Mills et al. (2014) state that differentiated learning refers to how teachers use every day learning to meet student needs, monitor student progress, identify special learning needs, and meet students' practice needs. This learning model can not only be used as a reference to encourage students to participate actively in the learning process but can also help students facilitate the diversity of student characteristics. Geel et al. (2019) state that teachers must emphasize the importance of "knowing students" in differentiated learning. It aims to determine the level of achievement and problems faced by students when learning mathematics. On the other hand, it can be known about students' pedagogical needs, learning interests, relationships with peers, how to motivate students, and what types of problem-solving strategies students can understand. Moreover, a differentiated instruction learning environment is significantly beneficial in advancing the students' mathematics self-efficacy, mathematics learning motives, and mathematical problem-solving skills (Lai et al., 2020).

Differentiated learning contains teacher benchmarks in facilitating student skills by providing various approaches to content, processes, and products (Ministry of Education, 2022a; Tomlinson, 2017). Learning can be adjusted to the student's ability from a content perspective. Learning can be adjusted to the student's ability from a content perspective. For example, students who need guidance can learn the three most important things related to the material, students who are proficient enough can learn the entire material, and students who are already very proficient can be given enrichment. Learning and mentoring (processes) can be differentiated according to the student's readiness. For students who need guidance, educators need to teach directly. For pretty proficient students, it can be started with modeling combined with independent work, practice, and review. Highly proficient learners can be given several lighters for independent tasks to highly proficient learners. Lastly, differentiation learning can also be done through the products produced.

Elizabath and Sangeetha (2018) stated that project-based learning naturally lends itself to differentiated instruction; it is student-centered, student-driven, and gives space for teachers to meet the needs of students in a variety of ways; thus, project-based learning can allow for effective differentiation in assessment as well as management and instruction. Their study explored different science topics in ninth grade, such as pollution, global warming, ozone depletion, the greenhouse effect, and acid rain. Cruz et al. (Guzman, 2019) support this by stating that project-based learning encourages differentiated teaching and enhances student-centered logic in mathematics education. In his study, Guzman (2019) utilized two teaching strategies: flipped classroom, project-based learning (PBL), gamification, and technologies such as 3D printing, 3D scanning, laser cutting, and mobile apps for undergraduate students. To date, the project-based learning model is one learning model that can facilitate student diversity (Rukmana et al., 2020). Project-based learning is highly recommended for developing individual and group skills in learning mathematics (Fisher et al., 2020). The above study agrees that project-based learning aligns with differentiated instruction. However, the study of the stages of different instruction (content, content, process) in mathematics project-based learning needs to be developed more.

Project-based learning is formed to be applied as a teaching approach because, at this time, students need to be able to deal with various real-life problems (Nushur & Astutie, 2019). Kokotsaki et al. (2016) argued that project-based learning is a student-centered active learning model characterized by student autonomy, constructive research, goal setting, collaboration, communication, and reflection on things that happen in everyday life. In addition, Rohmah et al. (2020) stated that project-based learning can increase student activity through scale projects or research in learning. Project-based learning can be applied to enhance students' mathematical ability (Yunita et al., 2021). Project-based learning methods focus on students and ensure students develop their knowledge and skills (Holmes & Hwang, 2016). Project-based learning stems from the educational vision of students taking greater responsibility for learning and applying the skills and knowledge acquired in the classroom to real projects (Rodríguez, 2012). It can excite mathematics learning and encourage independent learning (Septian, 2022). Project-based learning is proven to significantly affect students' learning achievement in mathematics, which greatly contributes to teachers' methodological teaching practices (Lazić et al., 2021) and can increase students' motivation to learn mathematics (Remijan, 2016).

The application of project-based learning can be started by asking questions that can raise problems, planning project activities related to the problems that have been given, scheduling project work, monitoring project activities, evaluating project work results, and closing with an evaluation of the project activity experience (Mahendra, 2022). Some of the principles applied in the implementation of project-based learning are the teacher's role as a facilitator, the similarity of mathematics topics studied by students, and the teacher's adaptation to project changes and active role in the investigation (Palatnik, 2022), another essential element is the solid teacher-student relationship (Morrison et al., 2021). Project-based learning can facilitate pedagogy that centers on student communication using virtual global collaboration project-based learning (Owens & Hite, 2022). Besides communication skills, project-based learning is one of the learning models that allows students to develop collaboration skills (Safarini, 2019). She used the learning design and student work rubric through the partnership for 21st-century skills. As a result, students worked together, shared responsibilities somewhat, and made substantive decisions, and their work was interdependent. Even though collaboration skills can be achieved as a result of learning through project-based learning, it can be affected by individual differences and social skills (Lee et al., 2015). This method requires students to be active in learning and collaborate in their groups to complete project assignments given by the teacher. Therefore, implementing project-based learning can influence their collaboration skills. To sum up, project-based learning is structured to include learners with different learning styles, as in small group or team-based collaboration; different competencies and technical preparation, as in interdisciplinary collaboration; different cultures and ways of working/thinking, as in cross-national collaboration (Ma, 2022). Unfortunately, limited research on students' collaboration skills using variative rubrics based on project-based learning is limited.

Four levels of collaborative skills are widely known in education/psychology from Johnson et al. (1998): forming, functioning, formulating, and fermenting. The skill of forming is directed towards the organization of the group and the establishment of behavioral norms within the group. At the functioning level, students are directed toward completing tasks and maintaining good relationships within the group. In order to function, group members must understand such requirements as the time limit for completing a task or activity or the step-by-step process for carrying it out. The skill of formulating is directed toward helping learners develop better reasoning strategies and a deeper understanding of the material being studied. Formulating is also targeted towards helping learners obtain maximum retention of the material. The highest-level skill is fermenting. This skill involves assisting students in exploring the material they have been exposed to in greater depth. When students can begin challenging one another's ideas, exploring different ways of looking at the material, and reconceptualizing the ideas being presented, they are utilizing the skills associated with fermenting.

According to Lai (2011), collaboration is collaborative interaction between students to solve problems. It is important to note that collaborative skills differ from collaborative projects (the learning process). Shared goals, high levels of negotiation, interactivity, and interdependence characterize collaborative interactions. Interactions produce complex explanations to enhance student learning. Project-based learning students will find any information and knowledge to make a successful collaborative project. The process of a collaborative project is to help each other solve problems within a group practically and learn how to improve problem-solving skills (Jewpanich & Piriyasurawong, 2015). Project-based learning is designed to solve the complex problem needed to understand knowledge. Through project-based learning, the inquiry process starts with a guiding question that will be directed to students in a collaborative project integrated into any curriculum subject (Saenab et al., 2018).

Collaboration is essential in the current Indonesian curriculum. The Ministry of Education, Culture, Research, and Technology (2022b) mentions six profiles that students need to acquire, one of which is cooperation. Cooperation involves collaboration, caring, and sharing. Students are expected to have collaboration skills, which means they can work together happily and show a positive attitude towards others. Along with the development of technology and information, there are some skills that students should master in the 21st century, including collaboration (Evans, 2020; Geisinger, 2016; Thornhill-Miller et al., 2023). Students are skilled in collaborating with other students with different interests, readiness, and learning styles. Collaboration skills will also foster good traits, such as supporting new ideas, respecting others, building relationships with others, and assuming responsibility.

The theoretical review above shows that differentiated instruction, project-based learning, and collaborative skills are essential to the current Indonesian curriculum, including mathematics subjects. Other than that, they are also essential skills for the 21st century. Unfortunately, the study of the different stages of differentiated teaching (content, process, and product) on project-based learning in mathematics is undeveloped. Additionally, research on using a variable rubric based on project-based learning to assess students' collaborative skills is limited. This study aims to implement differentiated instruction through project-based learning to assess student's collaboration skills.

We used a solid geometry theme as a natural sequence of teaching structure at the school where we studied. For that, we will propose two research questions:

1. How is differentiated instruction through project-based learning applied to solid geometry theme class?
2. How are students' collaboration skills in differentiated instruction through project-based learning in solid geometry class?

Methods

This research uses explanatory sequential design by collecting and analyzing quantitative data through observation results first, then following up through data collection and qualitative data analysis through interviews (Creswell & Creswell, 2022). This research was conducted in one of the junior high schools in Semarang, Central Java, Indonesia, with 32 students as subjects in April 2023. Declarations of consent were obtained, and data protection, anonymity, and confidentiality were respected. Solid geometry was a mathematical theme in this study. We carefully discussed with the mathematics teacher his teaching schedule and the unexplored students' collaboration skills status. He agreed with researchers to apply this study. We have two reasons for this decision. First, we focus on the learning approach, method, and students' collaboration skills. Second, we appreciated the students' time since 25% of mathematics class hours were used for an integrated school project.

Data collection techniques in this research used observation to implement differentiated instruction through a project-based learning structure on solid figures. We also utilized observation and student interviews to learn about students' collaboration skills. The data obtained in the observation is recorded on the learning observation sheet and students' collaboration skills sheet by giving a checklist (ü). The learning observation sheet contained the structure of differentiated instruction (content, processes, and product) and stages of project-based learning. The indicators used on collaboration skills (code A to J) in this research were adapted from indicators written by Johnson et al. (1998) presented in Table 1.

Table 1. Collaboration skills indicators

Code	Levels	Category
A	Students enter cooperative learning groups voluntarily	Forming
B	Students do not leave the group during the discussion	
C	Students share ideas and materials with group members to achieve goals	
D	Students give directions to the group	Functioning
E	Students help or clarification to group members	
F	Students summarize what they have just read or discussed	Formulating
G	Students presented the results of the discussion well	
H	Students ask questions to other groups about the results of the discussion presented	Fermenting
I	Students provide answers to questions from other groups	
J	Students provide conclusions from the entire *project* they have worked on	

After the observation stage was done, researchers conducted interviews with three students to find out why students did not implement indicators of student collaboration skills. Students who were interviewed were selected based on the results of observations of students' collaboration skills who had the fewest number of checklists (✓). There are 17 questions in the interview guide sheet that will be asked to students. The examples of those questions are:

1. What made you object to being in the designated group?
2. What made you leave the group?
3. What ideas or materials did you share with the group?
4. Why didn't you share your ideas or materials during the discussion?
5. What direction did you give to the group?

The data analysis technique used in this research is the Miles et al. (2014) which includes data condensation, data presentation, and conclusion drawing or verification.

Results

Student learning readiness assessment, student interest assessment, content differentiation

In the first meeting, differentiated instructions in class VIII F were opened by providing an assessment of students' learning readiness. This assessment contained 3 questions about the measurement of solid figures to be completed within 30 minutes. It focused on plane geometry. One of the examples of the question was “Mrs. Vinda has a (rectangle) field of land 24 m long and 15 m wide. She will make a roller-skating track for her son with a fee of Rp. 350,000. per m^2. Determine the total cost to create the track.”. The results of the assessment will be divided into four categories, namely: special intervention, basic, proficient, and advanced according to predetermined value intervals. The results of the student readiness assessment are obtained in Table 2.

Table 2. Results of student readiness assessment

Interval Value	Category	Number of Students
0-40	Special Intervention	2
41-65	Basic	16
66-85	Proficient	10
86-100	Advanced	4

Students in the basic category have the highest number (16). It was followed by the number of students in the proficient (10) and advanced (4) categories. Unfortunately, there were two students who were in the special intervention category. In this case, researchers provided a module that students could study outside of class hours. Additionally, they are also asked to work on some tasks that researchers will discuss with them in the next meeting. For the basic, proficient, and advanced categories, they were asked to study material from the regular textbooks.

After students had completed the student learning readiness assessment sheet, students were given a choice of pictures of solid figures (polyhedrons) to determine students' interest. The choices given to students included: cube, rectangular prism, triangular prism, and pyramid. Then students were asked to collect their assessment sheets according to the student's choice. Based on the results of the student interest assessment, the following is in Table 3.

Table 3. Results of student interest assessment

Type of solid figures	Cube	Rectangular Prism	Triangular Prism	Pyramid	Total
The number of students	16	16	-	-	32

The result of the student interest assessment showed us that students prefer cubes and rectangular prisms. For the next step, students were grouped based on the results of the student interest assessment. Additionally, there were categories of student readiness in each group.

Process, product differentiation and project-based learning

The steps in project-based learning were designing the project that will be completed during the learning process. Project-based learning begins by giving students a trigger question. In the second meeting, the researchers provided and explained the project that will be created. The project being designed is to create a replica of a city consisting of polyhedrons. Students were asked to make a replica of a city or village consisting of 4 types of polyhedrons and 2 combined polyhedrons. Students were given the freedom to choose what combined spatial structure they created and what materials they would use. This becomes a product differentiation used in differentiated learning. In this meeting, the researchers also announced members of the group and checked the work of students with special intervention. After designing the project, the next step in project-based learning was to arrange a schedule and job descriptions. The students must complete the project given within two meetings.

At the third meeting, students were expected to have at least 70% of the city replica made, namely 4 of the 6 buildings that students need to complete. Figure 1 shows the student’s work that contained three polyhedron (cube, rectangular prism, and triangular prism) and three combined polyhedron (cube-rectangular prism and cube- triangular prism). During the meeting, researchers monitored the project. Students were given the freedom to ask questions and express their opinions. When the researchers checked the progress of the student's project, several difficulties were found by the students. Among them was that students Figure have difficulty making pyramid shapes. Then, the researchers provided a solution by giving an example of making a pyramid using pyramid nets.

Figure 1. Student projects that achieve 70% progress

Then, at the fourth meeting students were given 30 minutes to resolve the deficiencies in their project. In this meeting the researchers assessed the project, the researchers asked one student representative from each group to draw a presentation lottery. Each group was given 15 minutes to present the results of the project they had created and answer questions from other groups. Students presented the results of the project by explaining what structures they made and how they made them. Other groups were given the freedom to ask questions during the presentation.

Students' collaboration skills

During the project, the researchers, assisted by colleagues, observed students' collaboration skills based on indicators of students' collaboration skills. The results of observing students' collaboration skills were obtained in Figure 2 as follows:

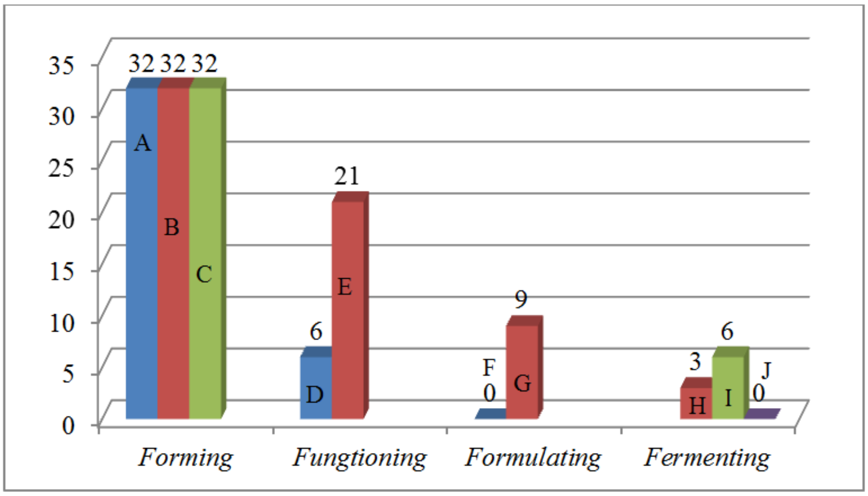

Figure 2. Graph of observation results of student collaboration skills

Based on Figure 2, it can be seen that the forming category obtained the highest number of collaboration skills. This shows that students’ collaboration skills in the forming category have been well implemented. Furthermore, all of the 32 students entered learning groups voluntarily (A), did not leave the group during the discussion (B), and shared ideas and materials with group members to achieve goals (C).

In the functioning category, there were six students giving directions to the group (D) and 21 students helping or clarifying to group members (E). Based on interviews with three students in the function category, the following results were obtained:

R : “Why don't you give directions to the group?”
S01 : "I am not sure what directions to give to the group. Moreover, another friend has already given directions."
S02 : "Directions have been given by a member of the group. Each group member only does what she has been directed to do."
S03 : "Everything has been shared by a member of the group. So, I just follow along."
R : “Why don't you provide assistance to the group when it encounters difficulties?”
S01 : "I am also confused about how to solve it"
S02 : "During the project work, there were no obstacles or difficulties. Everything was carried out well."
S03 : "I don't understand the material my group friends are asking about. So, I just do my part."

S01 and S03 have lower leadership and sharing abilities than S02. S01 and S03 felt confused when asked to give directions to their group, and they did not know how to solve the problems their group faced. Meanwhile, S02 felt more confident in giving directions and solving problems and did not find one or two things that were difficult in his group.

Unfortunately, students did not summarize what they had just read or discussed (F) and did not draw conclusions from the whole project they had worked on (J). In the formulating category, only nine students carried out indicator G (students presented the results of the discussion). Even so, the number of students was still higher than in the fermenting category. For example, three students asked questions to other groups about the results of the discussion presented (H) and six students drew conclusions from the whole project they had worked on (J). The code descriptions for the indicators of students' collaborative skills are shown in Table 1. Based on interviews with three students in the formulating category, the following results were obtained:

R : "Why don't you summarize the group discussion process?"
S01 : "I don't know if I was asked to summarize."
S02 : "I don't know if I was asked to summarize. I was also busy finishing the project."
S03 : "I don't know if I should summarize it."
R : "Why isn't your presentation optimal?"
S01 : "I am confused about what to present because previously it wasn't shared, so it was only presented by a few people."
S02 : "When I speak in front of my friends, I am sometimes embarrassed. I'm not used to presenting either."
S03 : "Everything was conveyed by another friend. So, I didn't get the opportunity to present the results of the discussion."

Based on the results of the interview in the formulating category, there was a lack of communication between students and researchers. Additionally, students were still embarrassed to speak in public.

In the fermenting category, the results showed that in indicator J there were no students who provided conclusions when presenting the results of their project. In indicator H there are three students who ask questions to other groups who are presenting project results, and there are six students who provide answers to other groups' questions. And in indicator I there were six students who answered questions given by other groups. Based on interviews with three students in the fermenting category, the following results were obtained:

R : "Why don't you ask the other groups questions?"
S01 : "I wanted to ask a question, but it was already asked by another friend."
S02 : "I don't know what to ask."
S03 : "I already understand the material. So, there's nothing to ask."
R : "Why don't you try answering the question asked?"
S01 : "I don't understand what he was asking. I also still don't understand the material."
S02 : "I am afraid that the answer I gave is wrong"
S03 : "Another friend already answered it."

Based on the results of interviews in the fermenting category, it can be concluded that this category is not optimal due to a lack of communication between students. When students do not have the opportunity to ask questions, students cannot understand the material presented well, and students will feel afraid to give the wrong answer. This fear can make students become inactive in learning and unable to participate optimally.

To summarize, among the 10 indicators of the collaboration skills category, students can only show a maximum of seven behaviors that match the indicators and only three students show this. There were five students who showed six indicators. Nine students were able to show five behaviors that were in accordance with the indicators. Seven students were able to show four indicators. Seven other students only showed three behaviors that matched the indicators. After all groups presented the results of their project discussion, the researchers evaluated the results of their project. The researchers said that during the project creation process, each group had its own advantages and disadvantages. There are groups that have good project results, but collaboration within the group is lacking. Likewise, other groups have good teamwork, but the project results are less than optimal.

Discussion

How is differentiated instruction through project-based learning applied to solid geometry theme class?

Students have different learning readiness. Some students can absorb the material easily with just one reading or listening, and some students have to read the material repeatedly to understand what is in the material. By doing so, learning outcomes can be achieved well, and no student feels left behind by other students because they do not understand the material to be presented; researchers provided modules that students can study outside of class hours. Thus, students can study the material presented according to each student's readiness. It is the application of content differentiation in differentiated learning. It is in line with (Sousa, 2011); the content differentiation used is to give students assignments with different difficulty levels. Giving students the freedom to choose the materials to be used to make their products was also described by Tomlinson et al. (2003). Students in the low category can work on questions that have a more accessible difficulty level. Students in the high category can work on questions with a higher level of difficulty. It allows students to challenge themselves without feeling overwhelmed. Content differentiation is the process of adapting learning materials to meet the needs of students with different readiness levels. It can be done in various ways, such as giving them more time to study references, giving assignments that have different levels of difficulty, or different ways to show their understanding of the material. After all, considering student readiness enables each student to achieve the learning objectives at his or her own learning pace and position (Gheyssens et al., 2021).

Through the results of the student learning readiness assessment and the student interest assessment, the researchers can design a project that will be used as a product of this study. This diversity of categories in assessing student readiness and interest was used as a benchmark for researchers to determine which projects will be given so that they can be used by all students who have different categories. The project created can be a lesson for students in the unique and basic intervention categories in order to increase students' readiness to receive learning. Meanwhile, students in the proficient and advanced categories can become peer tutors for other students who are still in the memorable and basic intervention categories so that students can complement each other and achieve maximum learning outcomes. Students who study in heterogeneous groups tend to achieve better than those in homogeneous groups. It is because students in heterogeneous groups will have the opportunity to learn different knowledge from one student to another and develop students' collaboration skills (Tomlinson et al., 2003). It aligns with Marzano et al. (2001), who state that when students can learn with peers with different ability levels, they will complement each other to achieve learning outcomes more optimally. Students who have high abilities can help students who have low abilities. Likewise, students with low abilities can help students with high abilities to expand their knowledge. Differentiated instruction aims to provide maximal learning opportunities for all students, so variation between homogeneous and heterogeneous teaching methods is essential (Gheyssens et al., 2023).

To sum up, stages in differentiated instruction were compatible with project-based learning. Even though the content differentiation that used student learning readiness assessment and student interest assessment was not in the stages of project-based learning, it was complementary to the learning instruction as it helped teachers and researchers to orient the students' understanding and interest. Project-based learning is a form of process and product differentiation application in differentiated instruction. The differentiated instruction through problem-based learning stages can be seen in Table 4.

Table 4. The differentiated instruction through problem-based learning stages

Differentiated Instruction	Project-Based Learning
Content differentiation Modules based on students' learning readiness Student interest assessment	
Process differentiation	Ask a trigger question Creating project design Develop scheduling
Product differentiation	Monitoring the Project Project Assessment Evaluating results

Apart from that, the learning implementation took four meetings (each meeting is 40 minutes). Moreover, it covered only the characteristics of polyhedrons. The implementation of project-based learning necessitates meticulous planning and support. Without meticulous design and implementation, it can devolve into mere activity without genuine learning (Lam, 2012). Thus, Balancing school ambitions with realistic expectations is a concern (Langelaan et al., 2024).

How are students' collaboration skills in differentiated instruction through project-based learning in solid geometry class?

While making the student project, the researchers observed the students' collaboration skills according to the students' collaboration skills indicators. The results of these observations show that students have different skill indicators. In the forming category, it can be seen that students have implemented the indicators. Skills at this level are directed toward organizing the group and establishing behavioral norms within the group (Krulatz & Christison, 2023). It shows that all students enter the cooperative learning group voluntarily, students do not leave the group during discussions, and students share ideas and material with group members to achieve goals.

Meanwhile, other categories, such as functioning, formulating, and fermenting, still need to show maximum indicators of collaboration skills. Moreover, it showed that the final two categories in the domain of fermenting skills are those least developed. The higher-order thinking skills of analysis, synthesis, and evaluation (Bloom Taxonomy) are most often associated with fermenting skills (Ma & Rong, 2022).

Therefore, the researchers chose three students to be interviewed further and found the factors that resulted in the discussion process and students' collaboration skills needing to be more optimal. In the function category, only six students gave directions to the group. Meanwhile, 21 students assisted their group. Based on the interview, students who did not show the function skills tend to have lower leadership and sharing abilities. Maxwell (2013) explained that an effective leader must be able to provide clear and easy-to-understand directions and be able to solve problems faced by his group. Students must also be able to inspire and motivate their group members to collaborate to achieve common goals. It was also explained by McShane and Glinow (2010) that one of the most essential roles of a leader is to provide clear and compelling direction to others. Based on the statement, it can be concluded that in the function category, the indicators shown are less than optimal due to students' varying leadership and collaboration abilities. Some students have higher and lower abilities. Several factors, such as personality, experience, and motivation, can influence it.

Based on the results of interviews with researchers, several factors cause the three students to not be optimal in the fermenting and formulating category. These factors are a lack of good communication between students and researchers, and students are still embarrassed to speak in public. Johnson and Johnson (2018) explain that effective communication between students and researchers, as well as students and other group members, is essential for the success of good cooperative learning. Effective communication can also improve students' collaboration skills. Effective communication is essential in learning, especially in project-based learning. Effective communication helps students understand the material presented, exchange ideas, and solve problems together. When students can communicate effectively, their' collaboration skills will improve (Crespí et al., 2022).

Technically, The stages of project-based learning have been implemented and supported by four principles: (1) crafting the driving question carefully to make connections between activities and the underlying conceptual knowledge that one might hope to foster; (2) providing scaffolds to students before completion of projects; (3) including multiple opportunities for formative self-assessment, and (4) developing social structures that promote participation and a sense of agency (Barron et al., 1998). The final principle is of particular significance in group work in project-based learning. The findings indicated that project-based learning enhanced students' learning efficacy only when the group processes exhibited the following four elements: (1) positive interdependence, (2) individual accountability, (3) equal participation, and (4) social skills (Cheng et al., 2008). The four skills above pertain to leadership ability, self-confidence, and communication, originating from the student's interview. Consequently, ensuring that the final stage of project-based learning is executed effectively is vital.

Conclusion

The stages of differentiated instruction were found to be compatible with project-based learning. The implementation of differentiated instruction begins with an initial assessment of student readiness; then, students are assessed student interest. After providing assessments to students, learning continues by implementing three essential aspects of differentiated learning, namely content, process, and product differentiation, located in the stages of project-based learning. Moreover, it is concluded that students' collaboration skills in the forming category have run optimally. However, students have not shown maximum results in other categories of collaboration skills, namely functioning, formulating, and fermenting. In the functioning category, the indicators for student collaboration skills are less than optimal due to students' varying leadership and sharing abilities. In the formulating and fermenting category, the students needed more communication and self-confidence.

Overall, these results show that the application of differentiated instruction through project-based learning positively influences students' collaboration skills. However, some indicators still need to be optimal. It implies that mathematics teachers should pay more attention to developing students' collaboration skills at every stage of learning. Differentiated instruction through project-based learning can be by presenting different projects and assignments according to individual needs to improve student collaboration. This research only focuses on students' collaboration ability after differentiated instruction through project-based learning, which is an effective ability. Other studies can be conducted by looking at cognitive abilities such as problem-solving, reasoning, or other abilities. Differentiated learning through project-based learning that considers technology integration can also be a favorable consideration for future research that must still pay attention to sound principles. Given the limited sample size, the findings should be considered provisional until further verification can be obtained from a more extensive study. Nevertheless, the findings provide a rationale for further research into implementing differentiated instruction through project-based learning. Moreover, this study can provide insight into the development of collaborative skills among students.

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Conflicts of Interest

Authors have no competing interests. In addition, the writers have addressed ethical concerns like plagiarism, misconduct, data fabrication and falsification, double publishing and submission, and redundancy

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Zuni Dwi Andriyani: Conceptualization, writing–original draft, methodology, formal analysis, editing, investigation and visualization; **Dyana Wijayanti:** Supervision, validation, formal analysis, Writing–review & editing, visualization; **Nila Ubaidah:** Supervision, validation, formal analysis, and visualization; **Ahmad Lutfi:** Writing–review & editing, and visualization. **Danyang Meng:** Writing-review & editing.

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