Teamwork skills assessment for STEM Project-Based Learnig

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Teamwork skills assessment for STEM Project-Based Learnig

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Abstract: This study developed an instrument for assessing undergraduate students' teamwork skills in designing and creating team product in the context of science, technology, engineering, and mathematics (STEM) learning. The development stage follows the stages of the R & D method developed by Barg and Gall. Teamwork skills instrument that has been declared valid qualitatively and quantitatively as well as are implemented in STEM project-based learning using one shot-case study design in three different courses. The teamwork skills are measured based on self-assessments, peer-assessment, and facilitator evaluations. The scores obtained from three sources of assessment are analyzed, using descriptive statistics and ANOVA. The results show that the teamwork skill instrument is valid and reliable to measure the students' collaborative skills in the STEM Project. In addition, the results of the three assessments showed that The STEM project-based learning is effectively able to train students' teamwork skills.

Keywords: Teamwork Skill; STEM Education; Collaborative Assessment

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Introduction

Over the last decade, the STEM (Science, Technology, Engineering, and Mathematics) education method has gotten a lot of attention from educators and researchers (Honey et al., 2014). This approach was selected with the aim of improving the quality of the curriculum and education. STEM, or science, technology, engineering, and mathematics, is a curriculum centered on the idea of educating students in four specific fields through an interdisciplinary and applied approach. Students who involve in the STEM education will get several benefits including being better problem solvers, self-reliant, innovators, inventors, creators, logical thinkers, and technologically proficient (Sen et al., 2018). STEM encouraged students to think critically. According to certain research, combining mathematics and science improves students' attitudes and interest in school (Suprapto, 2016), their motivation to learn (Julià & Antolí, 2019) and accomplishment (Wahono et al., 2020). Recently, studies by integrating science and education technology by applying "robotic" have shown that the use of technology in various disciplines will contribute to the nation (Newton et al., 2020).

STEM project-based learning is one of the learning models that may be utilized to meet the demands of STEM education while also preparing students to deal with technological advancements (Thibaut et al., 2018). STEM project-based learning is a project-based methodology for curriculum design that incorporates Science, Technology, Engineering, and Mathematics (STEM) (Shernoff et al., 2017). STEM project-based learning is distinct due to the design process and interdisciplinary training. The design strategy for STEM project-based learning starts with defining a well-defined outcome by selecting the project's goal and summative assessment (Tati et al., 2017). The students will next be given an undefined task to communicate their ideas for tackling a difficult problem in a creative way (Çevik, 2018).

For the instructor, there are five stages of STEM project-based learning that may be used (Tseng et al., 2013). Firstly, students are guided through the preparation step to comprehend the subject, scope, and problem. Secondly, students were needed to create a

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project based on their concept drawings and undertake the real test during the implementation stage. Thirdly, the presentation step requires students to showcase the project's outcome. Fourthly, the instructor was supposed to provide feedback or suggestions on the students' project during the assessment stage. Lastly, students were urged to make corrections in accordance with the evaluation at the level of rectification.

The workers agreed that having teamwork skills will be important for the student's future (Majid et al., 2019). According to the Association of American Colleges and Universities (AAC&U), 71% of employers see 'teamwork abilities and the capacity to interact with individuals in various groups' as learning outcomes that need to be improved in college (Hart Research Associates, 2010). Teamwork, on the other hand, is difficult to measure since it must be inferred from a slew of interconnected behaviors and attitudes (Careau et al., 2014). This makes it difficult for teachers and students to keep track of how collaboration develops and performs in the classroom (Sridharan & Boud, 2019). Furthermore, there is a lack of uniformity in how teamwork is conceptualized, which complicates measurement and evaluation.

Lecturers who want to prepare students to have collaborative skills in the workplace, usually use a STEM project-based learning model that provides group problem solving opportunities. However, in its implementation, the assessment of teamwork skills in STEM project-based learning becomes a problem because it is difficult to do. Several previous studies such as (Strom & Strom, 2011) and (Britton et al., 2017) have developed an assessment instrument on collaboration skills but not on the implementation of STEM project-based learning. Meanwhile, the focus research of STEM project-based learning is more on measuring 21st century skills learning outcomes (Triana et al., 2020); attitudes towards STEM (Suprapto, 2016); and STEM learning environment (Fraser et al., 2021).

Therefore, the current study's purpose was to create a long-term instrument with adequate psychometric indices of reliability and validity for fostering and evaluating collaboration in STEM project-based learning. The main goal was to promote collaboration as a critical component of undergraduate education.

Method

Research Design

This is a developmental study since it used the R&D (Research and Development) technique devised by Borg and Gall to construct teamwork skills instruments (GALL et al., 1996). Development research has two major goals: creating products (instruments) and determining how successful they are at attaining their aims. Preliminary investigations, product design, product development, product validation, product modification, field testing, and final products are all included in this study's research and development methods. Figure 1 describe the research design of the development of the teamwork skills instruments for the STEM project-based learning.

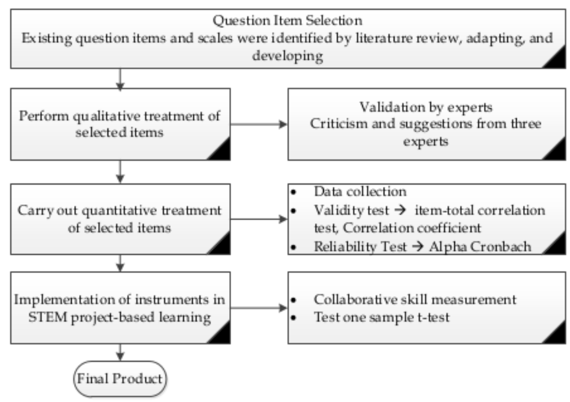

Figure 1. Research Design of Teamwork Skills Instrument Development

The final product in the form of a teamwork skills instrument was then carried out field trials involving 80 undergraduate science education students in semester II, IV and VI academic year 2021/2022 who received STEM project-based learning in their classrooms. The trial design of the collaborative skills assessment instrument in the classroom is described in Figure 2.

Figure 1. One-Shot Case Study Research Design

Description:

X = STEM project-based learning

O = Measurement of collaborative skills after the implementation of STEM project-based learning

Instruments

The instrument used in this study was teamwork skill questionnaire for STEM team-based project learning. The questionnaire was derived from other teamwork skills instruments, such as The Teamwork Skills Inventory (TSI) by Strom & Strom, (2011) and TeamUp Rubric by Britton et al., (2017)). The teamwork skill instrument provides guided student practice for peer and self-assessment of teamwork performance in STEM team-based project learning. The 24 items presented in six skills each are intended to find out whether a student contributes to team project, conducts planning and management, manages potential conflict, thinks critically and creatively, communicates with teammates, and gets along in the team. The items were rated on a five-point Likert scale, ranging from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree). The higher scores indicate more active collaboration skills of students in STEM team-based project learning.

Procedure of Teamwork Skills Measurement

Activities were directed primarily at teamwork, but one specific collaborative task, carried out in the fifth week of the semester, was selected for data collection. The course lecturers, together with suggestions from the research team, designed the assignment into an authentic team-based activity in which students were asked to create STEM-based products that were solutions to problems around students. The students then complete their self and peer assessments, while the evaluation facilitators finish the evaluations. To enable a sufficiently extensive engagement, it is necessary for team members to have worked together for a long amount of time; the recommended minimum is four weeks, (Strom & Strom, 2011).

Data Analysis

The qualitative data of the validation results of the teamwork skills instrument are analyzed descriptively. The gained average scores from the validator then are described regarding to criteria showed in Table 1.

Table 1. Validation Results Criteria

Score Interval	Category
1,0 ≤ VS ≤ 1,5	Poor
1,6 ≤ VS ≤ 2,5	Fair
2,6 ≤ VS ≤ 3,5	Good
3,6 ≤ VS ≤ 4,0	Excellent

The next stage is to do a quantitative test of the teamwork skills instrument by testing it on the Natural Science Education students. The test results were then tested using the item-total correlation test to determine its validity and the Cronbach Alpha test to determine the level of reliability.

The results of the teamwork skill measurement are based on three sources of information: self-assessments, peer-assessment, and facilitator evaluations. The peer assessments were determined by averaging the ratings given by each team member. Similarly, the external assessments were calculated by averaging the two facilitators' scores. The scores obtained from self-assessment, peer-assessment and facilitator's assessment of the teamwork skills are averaged and then analyzed, using descriptive statistics such as means and standard deviations. ANOVA was also performed to see whether there were any statistically significant differences between groups.

Result and Discussion

This research begins by developing question items and scales that will be used in the assessment of Teamwork skills of the STEM project-based learning. Based on the adaptation results from related study of Strom & Strom, (2011) and Britton et al., (2017), the grid of the teamwork skills instrument is explained in Table 2. Each item is identified with a verbal frequency description and graded on a five-point frequency scale ranging from 1 (never) to 5 (always).

Table 2. Indicators and Items of the Teamwork Skills Assessment

Indicators	Items
Contribute to STEM-based Team Projects	- Participate actively and receive a fair share of group work
	- Work skillfully on given STEM project tasks and complete them on time
	- Provide constructive feedback to team members' ideas
Planning and Management	- Take appropriate roles within the group (e.g., leader, note-taker)
	- Explain the goals and plans of the STEM project
	- Reporting to the team on the progress of the STEM project
Managing Potential Conflicts	- Displays appropriate assertiveness: not domineering, not submissive, or passive aggressive
	- Contribute appropriately to a healthy debate
	- Respond and manage direct/indirect conflicts constructively and effectively
Critical and Creative Thinking	- Evaluate evidence for differing opinions.
	- Use logic to respond to group thinking.
	- Think carefully before reaching a conclusion
	- Incorporating and building on other people's ideas.
	- Offers a new way of looking at problems.
Communicating with Teammates	- Share feelings, ideas, or opinions.
	- Speak clearly with acceptable vocabulary.
	- Limit lengthy comments so others can speak.
	- Listen to everyone and respect their views.
Join the Team	- Recognize individual contributions.
	- Accept criticism in a friendly manner.
	- Avoid using ridicule or blaming others.
	- Accept compromise to deal with conflict.
	- Keep trying when the task becomes difficult.
	- Express expectations about the group's success.

After selecting the questions, a qualitative test was conducted through validation of the instruments to the three experts. The results of the validation obtained scores in table 3.

Table 3. Validation Results of the Three Expert of the Teamwork Skills Instrument

Aspect Assessed	Average Score V1	V2	V3	∑Average Score	Category
Format	4.00	3.50	4.00	3.83	Excellent
Content	3.50	3.25	3.5	3.43	Good
Language	3.67	3.67	3.00	3.47	Good

Table 3 explained that the teamwork skills instrument in the STEM project-based learning is valid or can be used after refinement. In addition, the validator provides feedback for the development of the instrument. The validators' suggestions include: (1) In question item no. a and f, the sentences need to be corrected according to good and correct Indonesian rules; (2) It is necessary to use consistent words, for example, use the word "construction" not replaced by building; (3) There are multiple question items, so one needs to be omitted.

To validate the developed teamwork skills instrument quantitatively, the item-total correlation and Cronbach's Alpha test were performed to determine its validity and the level of reliability. The results of the validity and reliability tests can be seen in tables 4 and 5 respectively.

Table 4 Validity Test Results of Teamwork Skills Assessment

Item	R count	R table	Conclusion
1	.886**	0.297	Valid
2	.899**	0.297	Valid
3	.940**	0.297	Valid
4	.867**	0.297	Valid
5	.819**	0.297	Valid
6	.893**	0.297	Valid
7	.866**	0.297	Valid
8	.865**	0.297	Valid
9	.929**	0.297	Valid
10	.917**	0.297	Valid
11	.880**	0.297	Valid
12	.932**	0.297	Valid
13	.910**	0.297	Valid
14	.897**	0.297	Valid
15	.888**	0.297	Valid
16	.907**	0.297	Valid
17	.919**	0.297	Valid
18	.623**	0.297	Valid
19	.698**	0.297	Valid
20	.909**	0.297	Valid
21	.672**	0.297	Valid
22	.503**	0.297	Valid
23	.622**	0.297	Valid
24	.886**	0.297	Valid

8

Based on the results of the validity test in table 4, it is known that all the question items of the teamwork skill instrument can be used. In addition, Cronbach's Alpha value of 0.983 > 0.6 indicates that the measuring tool for teamwork skills in STEM project-based learning is reliable.

Table 5 Reliability Test Results of Cooperation Skills Assessment Instruments

Cronbach's Alpha	N of Items
.983	24

The STEM project-based learning was implemented in 3 classes of the Natural Science Education Study Program in different courses. In each course, students are asked to make a group STEM project which is a solution to a problem that occurs in everyday life within 5 weeks. In the fifth week, students were requested to complete an evaluation of the teamwork skills through self-assessment and peer-assessment. Meanwhile, the external evaluation was carried out based on collaborative assignments performed in the classroom for 1 hour in the third, fourth and fifth weeks. Each of the two course facilitators was appointed as a team to monitor and use teamwork skill instrument to assess the teamwork skills displayed by each member. Students are instructed to base their self and peer evaluations on their own and the teamwork skills their peers demonstrate throughout the course period. To make completion, collecting, and data input easier, evaluations are conducted using an online learning management system.

The data obtained from self-assessment, peer-assessment, and the external assessment of teamwork skills are then analyzed. The first analysis that was carried out after the collection of the three data 22 as by conducting a descriptive analysis as presented in Table 6.

Table 6. Results of Descriptive Analysis

	N	Min	Max	Mean	Std. Dev
Course 1					
Self	31	60.00	100.00	81.03	11.95
Peer	31	17.00	98.00	66.58	24.24
External	31	60.00	87.00	76.42	6.10
Valid N (listwise)	31				
Course 2					
Self	27	53.00	99.00	82.48	12.88
Peer	27	58.00	100.00	88.59	12.39
External	27	75.00	90.00	82.81	5.16
Valid N (listwise)	27				
Course 3					
Self	22	56.00	99.00	83.77	10.87
Peer	22	72.00	100.00	87.00	9.80
External	22	76.00	96.00	82.27	5.89
Valid N (listwise)	22				

Based on the table 6, the mean score of each assessment from each course is presented through the graph in Figure 1.

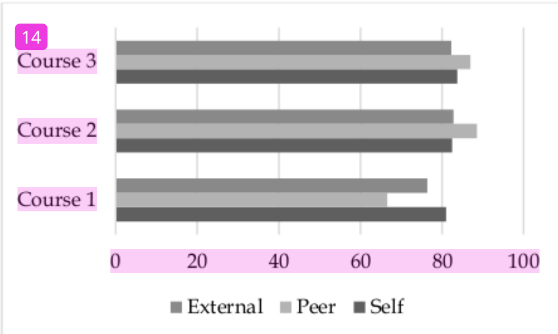

Figure 3. Graph of mean score of self, peer, and external assessment of teamwork skill in three courses

Figure 1 showed that the most consistent assessment of teamwork skills in each class is self-assessment. However, self-assessment is considered less valid. According to studies, self-assessed grades as a measure of performance are inaccurate, with considerable discrepancies between perception and reality (Sridharan & Boud, 2019). Incomplete awareness of self-competency and disregarding crucial information are two explanations for such mistakes. Therefore, peer and external assessment are needed to support self-assessment. However, the results of peer assessment showed inconsistency. This is because the developed teamwork skill instrument is not accompanied by a detailed rubric. Students should utilize a checklist or some sort of grading rubric to assess each other or as a group to illustrate what is being done, how acceptable it is, and what needs further work (Bores-García et al., 2020). Overall, the results of the three assessments showed that The STEM project-based learning is effectively able to train students' teamwork skills. According to Latip et al., (2020), STEM-robotic learning has a good influence on students' collaboration skills because teamwork and cooperation activities during the project's completion help each student grasp his and his friend's roles.

In the implementation of STEM project-based learning, three different modules were developed for three courses. In the first module, students were challenged to design and manufacture mixture separation equipment. In the second module students had to design and produce biotechnology products utilizing abundant materials around students' home and, in the last module, compiling scientific articles about the causes and impacts of natural disasters in Indonesia. Table 7 shows the results of the ANOVA test, which aims to identify whether there is a difference in teamwork skills between courses 1, 2 and 3. Prior to the ANOVA test, it was known that the homogeneity test results showed that the significant value was 0.029 > 0.05, which means that the population between classes is the same.

Table 7. The Results of ANOVA Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5130.205	2	2565.103	13.931	.000
Within Groups	40323.128	219	184.124		
Total	45453.333	221			

From the ANOVA test in table 7, the sig. value is 0.000, which is less than the significance level of 0.05, so the null hypothesis that the mean teamwork skills of 3 different courses are equal is rejected. In other words, the differences between the mean teamwork skills of three courses are statistically significant. This difference occurs because the team projects that must be performed by each class are different so that it affects student engagement. The lesson plan and implementation are different in three courses. According to Struyf et al., (2019), in a STEM learning environment, course planning and implementation may either encourage or discourage student participation. The results of Struyf's study showed that not only seeing students as a learning community is vital for their involvement, but also that the focus and direction of the lesson plan is frequently dictated by ideas generated by the students.

The graph of teamwork skills in Figure 2 explains the average score of students' teamwork skills on each indicator. In sixth indicators, it reached the largest average score of teamwork skills in three courses, namely 86.83. This shows that students already work well with teammates, especially when designing and creating projects aimed at solving problems that have been provided by the teacher. These results are in line with research conducted by Gasiewski et al., (2011) which shows that students in the STEM group exhibited curiosity and excitement about the option they had chosen. The topic of a project, which is chosen depending on the interests of the class. Then on the indicator of contributing to STEM-based Team Projects, the average score is 85.52. This shows that students take an active role in group work and accept a fair portion of it, as well as working well on assigned projects and completing them on time. The indicator communicating with teammates is 83.83 which shows that students can express their experiences, thoughts, ideas, or opinions, communicate clearly and use simple terminology, limit the length of their remarks so that others can speak, listen to everyone and respect their viewpoints, and encourage and appreciate others' contributions. The student's personal and soft skills development such as teamwork, communication and decision making, were significantly and directly impacted by the project-based learning module (Younis et al., 2021). The managing potential conflicts is 81.46 which shows that students may be forceful without being dictatorial, meek, or passive aggressive, contribute appropriately to a healthy discussion, and respond to and manage direct and indirect disputes constructively and successfully. The critical and creative thinking indicator is 80.70 which show that students' ability to consider points of view that differ from their own, to use logic to challenge group thinking or work methods, to think carefully about ideas before reaching conclusions, to build on others' ideas, and to offer new ways of looking at problems or events are all positive traits.

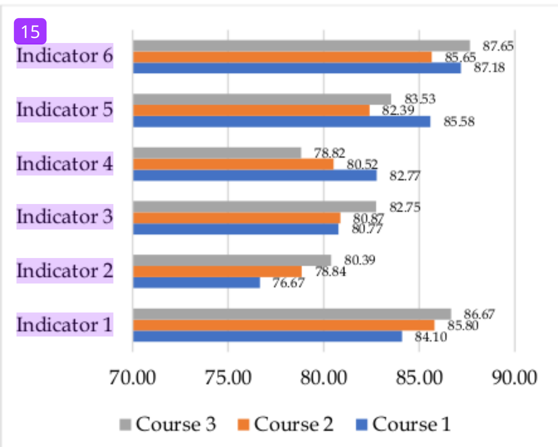

Figure 2. A graph depicting the average score for each indicator in the teamwork skills assessment.

The indicator for planning and management reached the smallest average score, namely 78.63 which indicates that students have been able to in presenting the STEM project's goals and plans, and informing to the team on the STEM project's progress but there are no positions for group members to fill, such as leader or note taker. The small average score of indicator for planning and management is caused by students' collaborative experiences so far have not been accompanied by instructor directives that they must share group member duties. They don't seem to mind who is the group leader or the note taker while they're working as a group. As stated by Latip et al., (2020) that every student in a STEM-Robotics class plays a distinct function in the group throughout project completion. The various responsibilities in groups are designed to ensure that each student has an active role in project completion.

Overall, the average score of each indicator teamwork skill indicated that the implementation of STEM project-based learning is able to train students' teamwork skills, especially on the six indicators, namely: contributing to STEM-based team projects, planning and management, managing potential conflicts, thinking critically and creative, communicating with teammates, and joining the team. This is also in line with research conducted by Lin et al., (2015) that the use of collaborative problem solving in STEM education can develop three collaborative problem-solving skills of students, such as, creating and keeping common understandings, taking appropriate action to solve the problem, and establishing and sustaining team organization. The relevant study by Awuor et al., (2022) also stated that project-based engineering course can develop teamwork competency and satisfaction in flipped learning.

The implementation of Project-Based STEM (PjbL-STEM) had positive effects on many 21st-century skills such as communication, and collaboration, problem-solving, creativity, critical thinking, responsibility, environmental awareness, and information-technology literacy (Baran et al., 2021; Osman et al., 2013). An engineering design method in STEM allows students to make connections between STEM domains and apply science knowledge and inquiry in a real-world setting. Through engineering practice and scientific investigation, students may build new knowledge and improve their learning (Kelley & Knowles, 2016). Students use technology and engineering as cognitive tools, solving issues using mathematical and scientific methodologies, generalizing essential concepts, and accumulating procedural knowledge (Lou et al., 2011). As a result, students are required to use authentic situations to develop and apply their integrated knowledge and cognitive abilities, such as problem-solving ability. Kelley & Knowles, (2016) also point out that, given the importance of the social aspect of STEM learning, such as collaborative skills is an important element in integrating the four STEM domains in situated learning, because students can construct their understanding by expressing and interpreting their thinking, and rich understanding by exchanging ideas and communicating and negotiating with others. As a result, it is critical to examine not just the cognitive aspects of STEM learning, but also the social.

According to the Organisation for Economic Cooperation and Development, (2017), collaboration in STEM learning has potential benefits over individual problem solving, such as more effective division of labor, incorporation of information from group members with diverse perspectives, experiences, and sources of knowledge, and enhanced creativity and quality of solutions through mutual feedback. These findings might pave the way for additional research into which task elements in relation to collaborative abilities are more challenging for students of different grade levels and prior knowledge levels. STEM learning with the project method can help students better work with three or even six people (Lavi et al., 2021).

Conclusion

7

Based on the findings of this research, it can be concluded that this study resulted in the instrument of teamwork skills in which the content validity and criterion-related validity were judged to be good. The result of the Cronbach Alpha test was also shown to be reliable. This instrument consisted of the six indicators, namely: contributing to STEM-based team projects; planning and management; managing potential conflicts; thinking critically and creative; communicating with teammates; and joining the team, in which the average score of each indicator showed students' teamwork skills in the problem-solving-STEM project. Overall, the teamwork skills instrument in STEM project-based learning presented by this study was effective in assessing students' collaborative skills.

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