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Collaborative Classrooms: Promoting Science Students' Collaboration Through STEM Learning Integration in the Era of Educational Resilience

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Abstract: STEM learning has increasingly been implemented in higher education, particularly in science education programs. In the aftermath of the global health crisis, the learning process has transitioned to a new normal, significantly different from pre-crisis practices. Numerous changes and challenges have emerged in science learning, particularly in fostering collaboration among prospective teachers in higher education. This research explores the nature of collaboration among prospective science teachers through the integration of STEM learning, employing a qualitative research method with in-depth observation as the primary data collection technique. Observations were conducted directly and supported by video recordings to ensure comprehensive data collection, with collaborative practices assessed using collaborative learning rubrics. The findings reveal that science education students have improved their collaboration skills through STEM learning integration, showing greater comfort in direct discussions and hands-on investigative learning activities, although some topics still require online discussions facilitated by e-learning platforms. Consequently, a blended learning approach is identified as the most effective method for integrating STEM learning in the current era to enhance collaboration in science education. Future research could further investigate the integration of STEM learning using hybrid learning models to promote collaboration among students.

INTRODUCTION

A successful education and professional career greatly depend on having 21st century abilities (Chaiyama & Kaewpila, 2022; Sulam et al., 2019; Vista, 2020). Because while giving students access to the courses in education programs is essential for their academic performance, it is insufficient in the twenty-first century (O'Lawrence, 2017). According to Rios et al., (2020); Short & Keller-Bell, (2019), regulations are in place to address the demands of the workers in industry and economy-oriented vocational domains by means of education. With the help of these educational rules, the goal is to educate people who can meet the demands of the twenty-first century. For the purpose of developing 21st century skills, multidisciplinary education programs are therefore provided as an alternative to education (Davies & Ryan, 2011; Harishree & Mekala, 2020; Thana et al., 2022; Trisdiono et al., 2019). Teachers need to be proficient in teaching pupils

the 21st century skills in an engaging manner. The goal of a successful 21st-century education is to teach students social, intellectual, and engineering skills in addition to fundamental abilities in science learning (Dixon, 2017; Sen et al., 2018). In this regard, Rios et al., (2020) outlines the competencies that people should possess in order to contribute in 21st-century society: literacy skills (the capacity to apply academic knowledge and competencies in practical situations), basic knowledge and competencies (academic knowledge and competencies), and 21st century competencies (the capacity to apply literacy and other competencies at any time to succeed in various domains of life).

Many industries now demand that people possess the skills including problem-solving, creative thinking, effective communication, being receptive to teamwork, accountability, etc., are suitable for the demands of the age (Jang, 2016; Suarta et al., 2017; Uluyol & Eryilmaz, 2015). While learning new information, students with 21st century abilities find it easier to adjust to changing circumstances (Dede, 2010; Kay & Greenhill, 2010). With these abilities, students can use those ability to adapt to the dynamic and ever-changing global community (Antonenko et al., 2014; O'Sullivan & Dallas, 2010). One of the learning approaches which could cultivate students 21st century skills is STEM integration learning approaches. Science, Technology, Engineering, and Mathematics (STEM) is an interdisciplinary approach that combines academic concepts with real-world lessons or problems.

This allows students to apply STEM subjects in a way that makes connections between the classroom, the community, the workplace, and international corporations. This will prepare them for the challenges of the twenty-first century. The three components of form are integrated content, supporting an integrated content, and integrated context. The application of STEM aims to foster thinking, reasoning, teamwork, investigation, and 21st century skills that students can apply to all aspects of their lives. The "Four" 21st century skills are critical thinking, creativity, communication, and collaboration (Fajrina et al., 2020; Permanasari et al., 2024; Sen et al., 2018). Collaborations is one of the most important skills that is needed in workface and to develop people skills to reach their work and life goals. STEM integration learning approach could help them to make collaboration activity intensively by making the project together (Han et al., 2021; Shofiyah et al., 2022).

Lately, the pandemic covid-19 was striking the world and affect to all sectors including educations. The people are difficult to make collaboration due to limited movement. At the beginning of pandemic covid-19, they also face the difficulties in technology adaptation for learning and adjusting to the learning method, model, and approaches. Two years has been through for struggling in online learning, now we have faced the post-pandemic era which technology is evolving rapidly. Even though technology is evolving rapidly and the habit of doing online learning is very strong during the pandemic, it cannot be denied that students still need face-to-face learning. It was might be affected to the collaboration action for students in learning especially using STEM (Science, Technology, Engineering, and Mathematics) learning approaches.

Some research has been done to investigate students' collaboration activity after pandemic, for instance developing augmented reality (AR) media-based STEM classroom to foster students' collaborations (Villanueva et al., 2020), design learning with online and virtual learning for whole semester in STEM classroom for engaged students' collaborations (McCollum, 2020; Owens

& Hite, 2022). Another researcher investigates direct teamwork to cultivate students' soft skills as relationship development, one of them is collaborations (Nurramadhani et al., 2021; Van Horne & Rakedzon, 2024). Therefore, this research has the uniqueness or novelty that distinct with others is to investigate how Indonesian preservice science teachers' collaboration skills and activity during STEM learning especially in post-pandemic era. This research has significancy and urgency for educations policy in university or other educations institutions in Indonesia as a consideration for classroom learning management, specially forming collaborative classes after the pandemic according to the characteristics and habits of students, so as to improve students' 21st century skills. So, the research aimed to investigate how is preservice science teachers' collaborations activity by using STEM integration learning approaches in post-pandemic era.

METHOD

Qualitative descriptive method was conducted in this research. Deep observations and semi- structured interview with subject to cultivate the data. The research was conducted to see student activities, which are active in learning by using STEM (Science, Technology, Engineering, Mathematics) integration approach. The observation is conducted in environmental learning. Students are asked to create a project based on the problems according to the topics in the learning. Students are asked to identify problems that exist in their surrounding environment based on topics, then they analyze related to the problem, so that they could create the solutions by making a prototype based on the design that has been made. The final stage is that they present their prototype ideas to their peers and lecturers. This research takes data related to how student collaboration in environmental learning using the STEM integration learning approach.

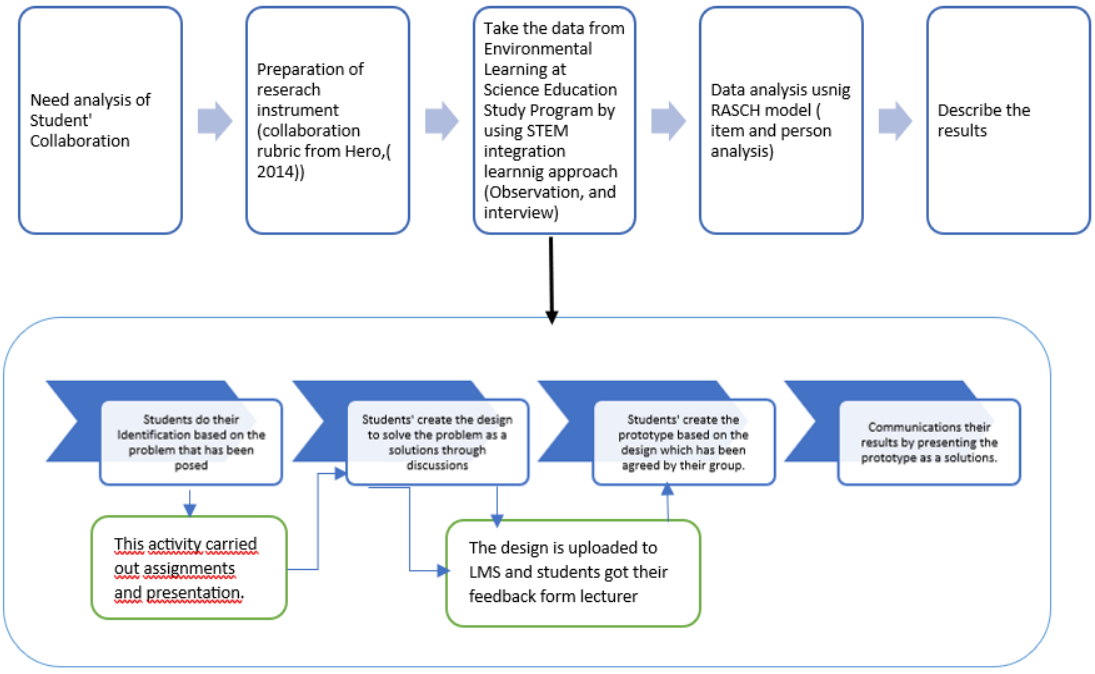

Figure 1. Collaboration Classroom Researchs' Flow Diagram.

This research was conducted on science education study program students as many as 15 freshman students. They were divided into several groups during learning that consist 3 students each group. Data analysis in this study used the

collaboration rubric developed by Herro et al., (2017). Table 1 is elaborate the collaboration aspect and indicators. The data that has been obtained is processed by the simple calculation of percentages for four general collaboration aspect and RASCH model approaches to see the collaboration among students and 12 indicators of collaboration that is improved.

Table 1. Collaboration Aspect and Indicators.

Collaboration Aspect	Collaboration Indicators
Peer interaction	Monitors tasks and checks for understanding with peers. Negotiates roles, and divides work to complete tasks. Provides peer feedback, assistance and/or redirection.
Positive communications	Respects others' ideas and compromises. Uses socially appropriate language and behavior. Listens and takes turns.
Multiple inquiry	Develops appropriate questions and methods towards solving the problem. Verifies information and sources to support inquiry.
Transdisciplinary approach	Discusses and approaches problem solving incorporating multiple disciplines. Shares connections to research or relevant knowledge. Negotiates relevant method or materials to solving the problem posed. Uses tools collaboratively to approach task.

RESULT AND DISCUSSION

The research which has been done in the classes of science prospective teacher elaborate the results of collaborative in science class with STEM integration learning approach. The learning topic around the environmental learning which demand the students to make a project as a solution that need collaboration to make it. Students 'collaboration has already in a good result based on simple statistic calculations. All the aspect of collaboration generally reached the half above the total percentages. Those aspect are peer interaction (76,3), positive communications (97,8), multiple inquiry (67,8), and transdisciplinary approach (76,7). The highest result is in the positive communication, and the lowest result is in multiple inquiry. The results are described in Figure 2.

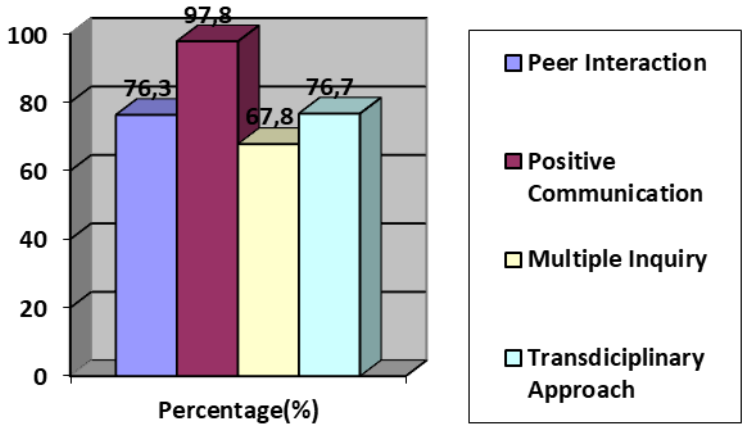

Figure 2. Students 'Collaborations Results in General.

However, using classical statistical calculations has its drawbacks. It can only determine the percentage of collaboration aspects in general. However, it has not been able to elaborate on each aspect with the indicators in it for each student. This can be done by statistical calculations with the RASCH approach. as described

in Table 2 related to reliability and validity testing pertaining data fit with the RASCH model.

Table 2. Reliability and Validity Person Item Results on Rasch Model.

	Mean Logit (SD)	Separation	Reliability	Alpha Cronbach	MNSQ (Infit-Outfit)	ZSTD (Infit-Outfit)
Person	28.9 (4.8)	2.42	0.85	0.87	0.98 – 0.88	0.06 – 0.21
Item	36.2 (5.8)	2.54	0.87		1.00 – 0.88	-0.02 – -0.08

From the reliability calculations using RASCH approach, the person and item are fits on the RASCH model. Because both of score are above the criteria (0.67). The validity scores also fit with RASCH model approach, because the score is included in the range; MNSQ (Infit-Outfit) is 0.5 – 1.5 and ZSTD (Infit-Outfit) is -2.0 – 2.0. So, the calculation of person and item based on students' collaborations could be continued using RASCH model approach. The item and the person value are elaborate based on Figure 3 and 4 that is adopted from wright map visualization on RASCH model analysis. This graph describes the item, means that which collaborative indicators that often and rarely appear when observing each person, means science prospective students.

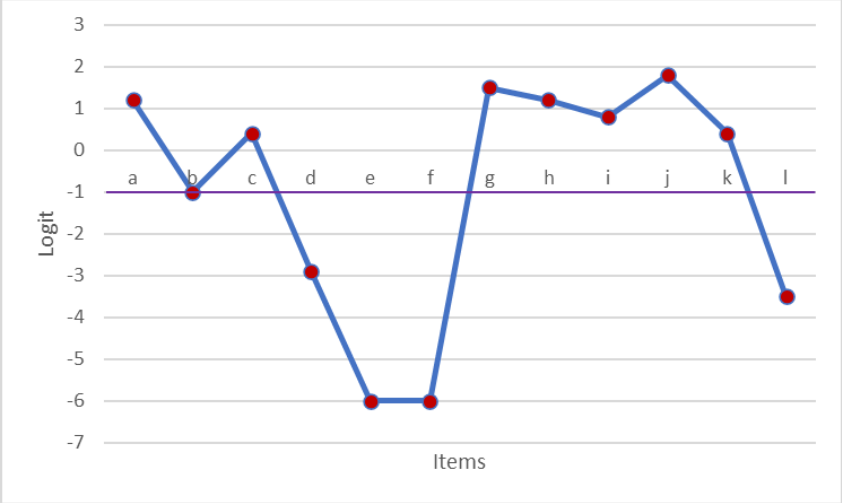

Figure 3. Item of Collaborative Learning Results (Wright Map Adaptations).

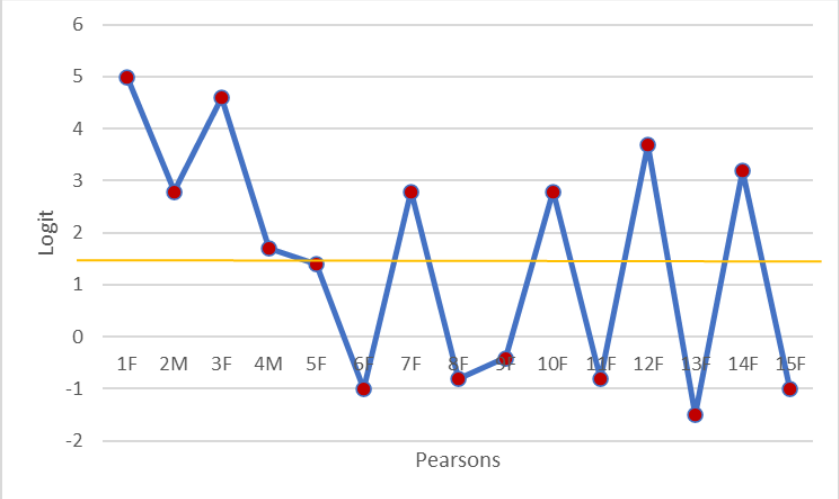

Figure 4. Students' Collaborative Learning Results (Wright Map Adaptations).

The indicator from each aspect that frequent appear in the students when collaboration happen, followed by purple line are indicator e (listens and takes turns) and f (respects others' ideas and compromises). There are aspect which average frequent appear in students, for instance, g (develops appropriate questions and methods towards solving the problem); a (monitors tasks and checks for understanding with peers); h (verifies information and sources to support inquiry); i (discusses and approaches problem solving incorporating multiple disciplines); c (provides peer feedback, assistance and/or redirection); k (negotiates relevant method or materials to solving the problem posed); and b (negotiates roles, and divides work to complete tasks), while the rare collaborative indicator that appear on students is j (shares connections to research or relevant knowledge). In additions, the students who less collaborative in the learning, followed by yellow line as an average are 13F. She has less effort to do the collaboration with her friends. She just sat quietly, seemingly not understanding what she had to do. When asked about the concepts related to the project, she could not answer. It is strengthened by the results of personal interview that she less motivated in the learning, she also said has health issues, and she could not really understand pertaining the material or project that she has done. The rest of them, who has strong desire to collaborate are 1F and 3F. They did the collaborations on the project as a leader and give their friends motivations to do the projects beyond the standard. The boys also have high willingness in collaborations, the boys also really helpful to did the hard things in the project such as sawing, welding, or such the other manual labor activity and they also give the logical steps to finish the project.

Based on the result that shown above, for clearly results, it is begun with the discussions. Positive communications have highest results in collaborative skills generally. It is caused by students has already honed their communication skills in every activity both in the learning classes or outside classes. Despite the covid-19 pandemic, their communication continues even though in different ways, namely using virtual face-to-face technology, such as google meet or zoom, WhatsApp, or other applications. Peer interactions aspect, has got the second bottom of the results. This shows that peer interaction is strongly influenced by direct and indirect interactions. Before the covid-19 pandemic, student interactions were carried out entirely directly in the classroom and outside the classroom. Meanwhile, when the covid-19 pandemic hit, the education system seemed to shut down. every component of education, including students and teachers, was forced to adapt to technology to be able to continue carrying out teaching and learning activities in the classroom. This creates an issues of adaptations difficulties for stakeholder, especially students. Lack of engagement, understanding of learning topics, and not knowing each other are inhibiting factors in the educational process. For now, in the new normal era, they also have to adapt from the former habituations, i.e., learning from anywhere, everywhere, and anytime by using technology. It called new normal means that there is something new to do, especially in education sector. Students need engagement to the teachers and peers in order to they understand the topics that is delivered in the classroom directly, in the other hand, they also need flexibility learning for the time,

places, and discussion with other in distance. So, the best approaches learning in new normal era for collaborations are hybrid learning. STEM learning integrations also has an important role to cultivate the peer interactions improve as aspect in collaborations.

Meanwhile STEM learning integrations approach which contain the project as learning outcome should consist of multidisciplinary knowledge (science, environment, social, engineering, economic, or others) to solve the problems. So that, it could make the students rise their curiosity, then ask some questions. STEM learning could cultivate students' curiosity and improved their collaboration to full fill their thirsty (Latip et al., 2020; Leas et al., 2017). However, the lowest results in collaborations aspect are multiple inquiry. Least of students done for making questions regarding their project. Based on the observation results, they done their project from an existing project using the same method that they got from the internet. This is the weakness of the rapid development of technology. Technology should be used as a search engine to support students' ideas. Not used as a plagiarism tool. That is why transdisciplinary aspect also got not the highest results. STEM learning integrations needs new original idea, so that is why needs a collaboration.

The four-collaboration aspect has several indicators of collaborative activity, if summed up there are 12 indicators which has been depicted in table 1. Based on the results from figure 2, shares connections to research or relevant knowledge indicator have the least appear in the students. It seems like the effect of rapid development of technology. They just put others' ideas to theirs, so they are not really understood what they have done on their project. Not all the students done this thing, some students had their original ideas as a solution through STEM learning integrations. It is contradictory with research result that said technology makes students easier to reach their collaboration and new idea (Dyer et al., 2015; Kornish & Hutchison-Krupat, 2017; Scalise, 2016).

STEM learning integrations as a learning approach which beginning with the problem that has to be solved by multidisciplinary approaches. So, it should be cultivated students' collaborations and make students could refer and connect it with relevant knowledge. The rest of 11 collaborations' indicators appear frequently on students' activity during STEM learning integration approaches. Those collaborations indicators could be promoted by the STEM learning using the project. It makes students collaborate each other's whether transfer knowledge or communications among them. The results of collaboration based on gender, the boys' and girls' students have the equal results of collaborations. They have the same role in collaborations results on STEM activity. STEM learning integrations also promote students' collaboration, either girls or boys. That results are contradictory with other research result which said that girls' students have outperformed in collaborations learning activity than boys (Saad et al., 2024). The other one also said that the evidence on the influence of gender diversity on team performance is more ambiguous and depends on a number of contextual circumstances. Given the importance of collaboration in science, encouraging women to pursue careers in science and technology can have a good impact on both fields (Bahtiar et al., 2023; Bear & Woolley, 2011). In fact, in this study, gender was not the main factor that make students collaboration work well, but rather socially-shared regulation among students is become one of the keys to creating a positive classroom environment in which students influence

and motivate each other (Calabrese et al., 2023; Idris et al., 2023). Motivational and emotional consequences are influencing students' collaborative activity and vice versa (Järvenoja et al., 2020; Järvenoja & Järvelä, 2013).

This research more focused to investigate how is students' collaborative activity from each its indicators by using STEM integration learning in post-pandemic era. This research also could become initial research for other further research pertaining strategy, approach that related to digital era which rapidly growth and influence educations area. Although we have entered a massively digitalized era, hands-on experience is also very important for students. So, blended learning is able to accommodate students' collaboration skills. Suggestions for further research to optimize students' collaboration skills. It is recommended to be able to research further on hybrid learning in the STEM learning integration approach. It is also recommended for learning that can improve student collaboration are provide interesting topics that can be discussed from various disciplinary perspectives, using the latest technology, using flexible learning strategies, and using STEM approaches so that students can continue to explore their inquiry and curiosity so that they can continue to collaborate with their colleagues. This research has an urgency in the field of education, especially how students' collaboration skills can be optimized as 21st century skills needed in the future work field. In contrast to other studies, that only discuss the implementation of the STEM approach is only in full digital learning (McCollum, 2020; Owens & Hite, 2022; Wiyono et al., 2022). On the other hand, other studies also only discuss that students' collaboration skills can only be optimized with full offline activities (Fajrina et al., 2020; Van Horne & Rakedzon, 2024). Whereas in the post-pandemic era, students need a combination of both proportionally as the results described in this research.

CONCLUSION

Based on the results and discussions, it reveals that science students have developed in collaborations by using STEM learning integrations. Students are more comfortable in discussions directly and make investigations learning directly, but somehow, they also need online classroom to discuss for several topics by using e-learning. So, the best STEM learning integrations in post-pandemic era to improves students' collaborations in science learning is blended learning. However, this research has limitations, one of them is lack of observers which should be at least the number of student groups.

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