Developing an Authentic STEM Learning Ecosystem through Festival-Based Innovation Programs in Junior High Schools

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ABSTRACT

STEM learning is a widely used approach to prepare students for 21st-century skills. However, STEM implementation in schools still tends to focus on the final product of projects and partial activities, thus failing to fully deliver authentic learning experiences. This study argues that an authentic STEM learning ecosystem can be effectively developed through festival-based innovation programs in junior high schools. Employing a descriptive mixed-methods approach with 4,821 students across 17 schools, the program integrates STEM learning, project development, competitions, exploration visits, and exhibitions. Data from observation, documentation, evaluation questionnaires, and participant reflections were analyzed using a nine-element authentic learning framework. Results reveal that this integrated festival-based approach fulfills all authentic learning elements and achieves strong outcomes: meaningful learning (95/100), participant engagement (91/100), insight from laboratory visits (92/100), public communication of projects (89/100), and team collaboration (95/100). These findings demonstrate that festival-based innovation programs can deliberately create a contextual, collaborative, and problem-oriented STEM learning ecosystem, thereby providing an effective model for strengthening students' 21st-century competencies.

Keywords: authentic STEM, STEM learning ecosystem, festival-based learning, authentic learning, 21st-century skills

INTRODUCTION

21st-century developments demand that students possess critical thinking, creativity, collaboration, communication, and problem-solving skills (Battelle for Kids, 2019). Science, Technology, Engineering, and Mathematics (STEM) learning has emerged as a widely adopted approach that integrates multiple disciplines through problem-based learning and contextual projects (Ye & Xu, 2023). Empirical studies indicate a correlation between STEM learning and enhanced students' critical thinking and creativity (Komalasari et al., 2024).

STEM learning focuses not only on mastering academic concepts but also on applying knowledge in real-life situations through exploration, design, experimentation, and innovation. Through the STEM approach, students are encouraged to develop solutions to real-life problems by integrating scientific, technological, engineering, and mathematical thinking skills collaboratively (Indriyantia, 2025). Furthermore, STEM learning is considered effective in enhancing creativity (Hanif, 2019), student engagement (Franco, 2017), and problem-solving skills (Hayuana, 2023) through authentic, project-based learning activities (Beier et al., 2019).

Despite its potential, the implementation of STEM in schools continues to face several challenges. Frequently, STEM learning prioritizes project outcomes and short-term activities over the student learning process (Shively et al., 2018). As a result, critical aspects such as learning experiences, collaboration, real-world interactions, and the development of communication and problem-solving skills are often underemphasized.

To overcome these obstacles, an authentic STEM learning ecosystem is necessary. Herrington and Oliver (2000) explain that authentic learning has nine main elements: authentic context, authentic tasks and activities, access to expert performances, multiple perspectives, collaborative construction of knowledge, reflection, articulation, coaching and scaffolding, and authentic assessment. Through these elements, students can gain more meaningful and contextual learning experiences.

To address these needs, a festival-based STEM program was designed to establish an authentic STEM learning ecosystem in junior high schools. The program includes STEM learning activities, competitions, exploratory visits to university laboratories, workshops, seminars, and project exhibitions in public venues. These activities offer students authentic learning experiences by fostering collaboration, facilitating interactions with experts, promoting public communication, and enabling the application of STEM concepts in real-world contexts.

METHOD

This study used a descriptive mixed-methods approach to analyze the development of an authentic STEM learning ecosystem through a festival-based innovation program (Creswell & Plano Clark, 2018). The analysis used Herrington and Oliver's nine elements of authentic learning as the main research framework (Herrington, 2000).

The program involved 4,821 students from 17 junior high schools. In the initial phase, all students created problem-based STEM projects as part of co-curricular activities at school. Subsequently, each school sent two top teams to participate in a STEM competition.

Participants then participated in a STEM Exploration Visit to campus, which included seminars, workshops, and laboratory visits. The

series of activities concluded with a STEM Exhibition at a mall, where the projects were presented and publicized.

Data for this research were collected through observation, activity documentation, participant evaluation questionnaires, and participant reflections. Quantitative data were derived from participant evaluations using a rating scale, while qualitative data were obtained through participant observation and reflection during the activities. Data analysis was conducted descriptively by mapping each activity to Herrington and Oliver's nine elements of authentic learning to identify how festival-based programs foster authentic, contextual, and collaborative STEM learning.

FINDINGS AND DISCUSSION

Based on observations, documentation, participant reflections, and evaluation questionnaires, the following are the findings on the nine elements of authentic learning identified by Herrington and Oliver.

Table 1:
Implementation of Authentic Learning Elements in STEM Festival Programs

Element Authentic Learning	Festival STEM Activities
Authentic Context	- STEM project with the theme: SDGs Zero Hunger - Exhibition at the mall
Authentic Tasks and Activities	- Project - Experiment - Workshops - Presentation
Access to Expert Performances	- Seminars - Workshops - Campus laboratory visits
Multiple Roles and Perspectives	- Interaction with lecturers, judges, visitors, and other participants
Collaborative Construction of Knowledge	- Project development and teamwork
Reflection	- Evaluation: Reflection on project experience

Articulation	- Project presentation, Public exhibitions
Coaching and Scaffolding	- Assistance for teachers, lecturers and facilitators
Authentic Assessment	- Project assessment - Presentation - Exhibitions

1. Authentic Context

Authentic context is a learning condition that presents real problems, allowing students to learn in contexts relevant to everyday life (Herrington, 2000). In STEM learning, authentic contexts help students understand that science and technology can be used to solve various societal problems (Aynas, 2021). In this festival-based STEM program, authentic context is achieved through a project theme focused on the Sustainable Development Goals (SDGs), particularly Zero Hunger. A total of 34 projects that passed the competition stage were developed in accordance with the theme of food security and innovative food-related solutions. Students developed various projects on food innovation, food technology, and sustainability solutions that address real needs in society.

The following are several project titles created by students.

- KALEG'S Emulsion: Functional Food based on Invasive Fish Oil Enriched with Vitamins A-D-E-K from Vegetable Waste
- Effectiveness of Bangun-bangun Leaves as a Supplemental Food in Increasing Breast Milk Production and the Immune System in Nursing Mothers
- NUGGO (Zero-Waste Vegetarian Nuggets as a STEM Solution for Stunting Prevention and Sustainable Nutrition Security)
- Technology Eco-Efficient-Effective-Economical (T-4E) Water System Based on Arduino Multi-Sensor

2. Authentic Tasks and Activities

In STEM learning, authentic tasks focus not only on the final product but also on the process of exploration, experimentation, collaboration, and presentation of ideas. Authentic tasks and activities are learning activities that mimic real-life situations and tasks, enabling students to engage directly in thinking, problem-solving, and decision-making (Taconis & Bekker, 2023). In this festival-based STEM program, students engage in various authentic activities, from designing projects and conducting experiments to solving problems, participating in laboratory workshops, and presenting projects to judges and visitors.

Participants were asked questions via an evaluation questionnaire to assess their engagement with the STEM Festival. The following questions were included in the participant evaluation questionnaire:

- I was actively involved in the STEM project development process.
- I was directly involved in laboratory experiments.
- I was actively involved in explaining the project to visitors.

The evaluation results showed that this program achieved a participant engagement rate of 91/100. These findings demonstrate that the festival-based program can provide authentic, active, and contextual learning activities for students.

3. Access to Expert Performances

Herrington and Oliver (2013) explain that authentic learning needs to provide students with access to observe how experts think, work, and solve problems, so that students gain a more contextual and meaningful learning experience. In this festival-based STEM program, access to expert performances is provided through STEM Exploration Visit activities at university campuses, which include seminars, practical workshops, and laboratory visits. Students have the opportunity to learn directly from lecturers, laboratory facilitators, and students about the application of science and technology in the real world. During competition activities, participants also receive feedback from the jury regarding their project.

To measure the level of interaction with experts, students are given an evaluation questionnaire with several questions.

- The jury's input helped me better understand how to develop the project.
- I gained new insights from the jury's discussions and assessments.
- The judges' explanations and questions helped me understand the application of STEM in the real world.
- The seminar material is presented clearly and is easy to understand.
- The seminar helped me understand the basic concepts of food engineering and biotechnology.
- Explanations during the visit were easy to understand.
- This exploration visit increased my understanding of science and technology.

The evaluation results show that direct interaction with the academic environment and experts helps students understand the application of STEM in a more real and contextual way, as evidenced by the results of a questionnaire regarding the clarity of seminar material, which received a score of 89/100, while the contribution of laboratory visits in broadening participants' insight reached 92/100. The jury also helped the participants by providing feedback; this was in line with the results of the questionnaire, which assessed the jury's professionalism and objectivity in providing input, reaching (92/100).

Through reflection, participants also wrote down the things they liked most, namely. Below are some of the reflections that participants wrote.

> The thing I like most is the practicum because, during the practicum, I was guided by the lecturer, so I could try it directly and see the process in real life, not just listen to the explanation. That way, it was easier for me to understand the material, and it felt more exciting because I could be directly involved in the activity (Respondent).

From the participant's reflection above, the lecturer's guidance through practical work and direct explanations helped participants understand the material better. These findings support that by gaining access to experts, participants understand the material more deeply and authentically.

> Seminars are the activities I like most because they provide insight into the world's biggest environmental problems (Respondent).

Through seminars, participants gain in-depth knowledge from lecturers as resource persons. These findings indicate that festival-based programs can provide participants with access to information from experts in their fields that supports authentic STEM learning.

4. Multiple Roles and Perspectives

In this festival-based STEM program, students gain diverse perspectives through interactions with teachers, lecturers, judges, exhibition visitors, and participants from other schools. To determine whether the STEM Festival activities created an environment rich in interaction, the researcher summarized the students' reflections on what made the most impression on the participants as follows.

> In my opinion, the most impressive experience for me was being able to learn about other school projects, share ideas, and discuss them together (Respondent).

> The most impressive thing for me was seeing other friends' very good and creative work, which motivated me (Respondent).

> The most impressive experience for me was meeting many people interested in our products, as well as other STEM groups (Respondent).

> Meeting other school friends and seeing other interesting and inspiring product presentations were valuable experiences for me (Respondent).

> I enjoyed introducing our project and observing other projects at the exhibition, which helped me identify and appreciate the unique features of various innovations (Respondent).

> It was an extraordinary experience because I was able to gain knowledge from other school friends with a very interesting product (Respondent).

During the activity, participants not only presented their own projects but also saw innovative ideas and solutions from other teams with different approaches to the Zero Hunger theme. In addition, direct interaction with visitors and judges provides students with opportunities to receive questions, input, and new perspectives on the projects being developed. These findings indicate that festival-based programs can create learning environments rich in interactions and perspectives for authentic STEM learning.

5. Collaborative Construction of Knowledge

Learners work in teams to design projects, conduct experiments, resolve obstacles, and present project results in this festival-based STEM program. The collaboration process is visible during the project development, competition, and exhibition stages. The results of the questionnaire evaluation showed that the improvement in teamwork skills scored 95/100, while the ability to work together during exhibition activities scored 90/100. Apart from that, many participants wrote reflections that the discussion process, division of tasks, and teamwork were the most memorable experiences during the activity.

Students also explained that this activity increased collaboration among team members; some participants even said that collaboration was the most important thing.

> The most important lesson I learned was the importance of teamwork, communication skills, and quick decision-making. During the exhibition, we had to help each other, have the courage to explain products to visitors, and sometimes quickly determine steps when unexpected situations arise (Respondent).

> After participating in this activity, I realized that group collaboration between teams is very important (Respondent).

> Good cooperation is very important because it can reduce the burden on (Respondent).

These findings show that festival-based programs can build a collaborative culture for authentic STEM learning, where students can exchange ideas, share roles, and develop solutions collectively.

6. Reflection

In this festival-based STEM program, the reflection process is evident in activity evaluation, participant reflections, and experiences gained while developing and presenting projects. This activity invites students to reflect on their experiences. Through the help of a questionnaire instrument, students answer the following reflection questions:

- Are there any other benefits gained by participating in this STEM competition?
- What was the most impressive thing about this activity?
- Obstacles you experienced while participating in the competition:
- Suggestions or input to make this activity better in the future:
- What is the most important lesson you learned?
- If you were to repeat this activity, what would you like to improve?

Students said they learned to overcome technical obstacles, manage their time, work together in teams, and build their courage to speak in public. Apart from that, exhibition activities provide a reflective experience for participants, who must answer visitors' questions and receive direct feedback. These findings indicate that festival-based programs not only produce STEM projects, but also help students understand the learning and self-development processes they experience during the activities.

7. Articulation

Herrington & Kervin (2007) explain that authentic learning needs to encourage students to communicate the knowledge and solutions they produce, thereby enabling communication and argumentation skills to develop optimally. In this program, articulation is achieved through project presentations, pitching sessions, and STEM Exhibition activities at the mall. Students must explain the idea, process, and benefits of the project directly to the jury and visitors.

In the activity evaluation questionnaire, the following questions were included:

- I feel confident when answering visitor questions.
- I can explain projects clearly.
- I feel ready when I appear on stage.

The evaluation results showed that the participants' ability to explain the project received a score of 89/100, while their confidence in answering visitors' questions reached 88/100.

Apart from that, many participants said that speaking in public and explaining the project were the most memorable parts of the activity. For example, it can be seen in the following participant comments:

> The most memorable experience for me was when giving a presentation and explaining the product to visitors. Through these activities, I can share ideas and concepts for the products we make and interact directly with many people. This is

> a very valuable experience because it trains my self-confidence and communication skills (Respondent).
>
> The most impressive experience was being able to show and explain my product to others, meet other school friends, and win 2nd place in the presentation competition at the event (Respondent).
>
> The most memorable experience was when presenting on stage (Respondent).
>
> I was impressed when I presented to people who visited the booth (Respondent).
>
> I can be confident when presenting on stage (Respondent).
>
> During the presentation to the jury, friends, teachers, and visitors (Respondent).
>
> The most impressive thing for me was the presentation to people we didn't know (Respondent).
>
> When presenting, I felt that I could speak in front of many people without fear (Respondent).

Participants also reported several obstacles during presentations, such as nervousness and panic due to inadequate preparation. This shows that presentation activities concern them and are something they need to improve.

These findings show that festival-based programs can develop communication skills and convey ideas through authentic STEM learning.

8. Coaching and Scaffolding

Mentoring and guidance for students are important in STEM learning (Belland, 2017). In this program, students receive assistance from supervisors, workshop facilitators, lecturers, and committee members throughout the project development process through to presentation. Assistance is provided through project direction, discussion of ideas, technical support, and guidance during practicums and exhibitions. In the completed evaluation questionnaire, participants wrote that the implemented activity model had provided support for the learning process.

> The activity model is a project-based festival, with the assistance of a professional mentor, so that participants can receive guidance and input during the innovation-creation process (Respondent).

The STEM Exploration Visit activity also provides students with the opportunity to receive direct explanations and demonstrations from laboratory facilitators. These findings show that festival-based programs

can create a learning process that supports the development of students' abilities through ongoing mentoring and guidance.

9. Authentic Assessment

In this festival-based STEM program, assessment is carried out through project presentations, exhibition appearances, discussions with judges, and evaluations of products and teamwork. This is in accordance with Herrington and Oliver's statement that authentic learning requires assessments that focus not only on final results but also on the processes of thinking, collaboration, communication, and problem-solving.

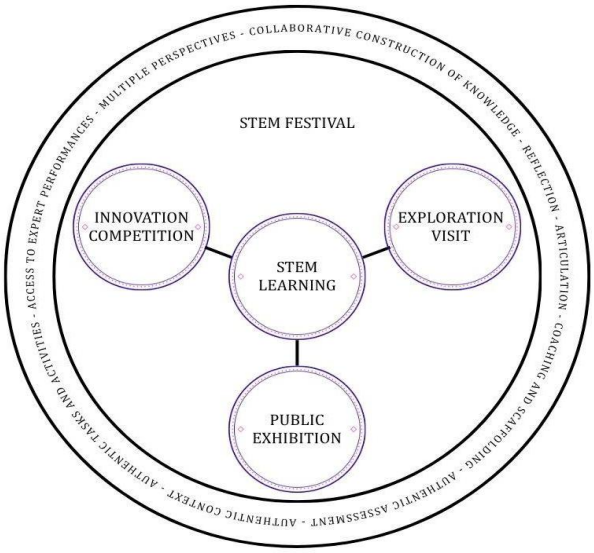
Students wrote that experience in public spaces was very valuable. The entire exhibition was very memorable because it was a new experience; participants got to open a stand and explain the product to others. A number of questions were included in an evaluation questionnaire for activity participants, as follows.

- I gained a meaningful learning experience.
- Overall, this exploration activity was useful for me.
- Tell us about your most memorable experience during the exhibition.
- This activity is worth recommending to other students.
- The competition motivated me to take part in similar activities in the future.
- The competition encourages critical thinking and problem-solving.
- The competition encourages creativity and innovation.
- The competition increased my interest in the STEM field.
- The practicum trained me to think critically and solve problems.
- This activity encouraged me to learn more about STEM.

The evaluation results showed that the meaningful learning experience received a score of 95/100, and the participants' motivation to participate in similar activities in the future reached 93/100. These findings indicate that festival-based programs can provide a more authentic assessment system because students are assessed through real-world performance and direct experience in STEM learning.

Overall, the series of festival-based STEM activities demonstrates that authentic STEM learning is constructed through the integration of multiple interconnected learning experiences. Project learning, STEM competitions, STEM Exploration Visits, workshops, seminars, and STEM Exhibitions collectively form a learning ecosystem that provides contextual, collaborative, and sustainable learning experiences. Each activity plays a distinct role in supporting students' development of knowledge and skills and in providing authentic learning experiences. The integration of these activities is illustrated in the following image.

Figure 1:
Integrated Festival-Based Authentic STEM Learning Ecosystem



The activities within the festival-based STEM program are structured as a complementary and integrated system to build an authentic STEM learning ecosystem. Learning and development projects provide a foundation for students to explore ideas and address real-world problems. STEM competitions promote creativity, critical thinking, and the development of innovative solutions. STEM Exploration Visits broaden students' perspectives through direct interaction with experts, laboratory environments, and real-world applications of STEM. The STEM Exhibition offers an authentic opportunity for students to communicate their ideas and projects directly to the community.

Each activity serves a distinct function while collectively supporting the development of authentic STEM learning. The absence of project development limits students' opportunities to explore ideas and solutions. Without competition, there is less motivation to enhance creativity and project quality. The lack of exploration visits reduces opportunities for direct learning from experts and real-world environments. Similarly, without exhibitions, students miss authentic experiences in public communication and presentation. Therefore, integrating all activities is essential for creating an authentic STEM learning ecosystem that is contextual, collaborative, and meaningful for students, surpassing the outcomes of classroom-based project learning alone.

A prominent feature of this program is the implementation of the STEM Exhibition in public spaces. Exhibitions serve not only as platforms for displaying project outcomes but also as opportunities for authentic learning through direct interaction with the community. Students learn to explain ideas, answer questions, receive feedback, and communicate

directly with visitors. This experience creates a realistic learning environment, as students are evaluated not only by teachers but also by a public audience, similar to professional and real-life contexts. Consequently, exhibitions play a critical role in developing students' communication, self-confidence, and presentation skills within authentic STEM learning.

Additionally, festival-based STEM programs support the development of 21st-century skills. Evaluation results indicate that these activities enhance students' critical thinking, creativity, collaboration, communication, and problem-solving abilities. The processes of project development and teamwork foster collaborative decision-making, while presentation and exhibition activities strengthen communication skills and public speaking confidence. Through contextual and real-world problem-based learning experiences, students gain a deeper understanding of STEM applications in everyday life (Nugroho, et al., 2022).

Nevertheless, the program's implementation faces several challenges, including time management, activity coordination, technical project preparation, and limited facilities at certain stages. Some participants also encountered difficulties when presenting and responding to visitors' questions. These challenges, however, contribute to the authentic learning process by requiring students to adapt, collaborate, and solve problems in real situations. Therefore, festival-based STEM programs have the potential to be further developed as a contextual, collaborative, and sustainable model for authentic STEM learning in schools.

CONCLUSION

The festival-based STEM program successfully established an authentic STEM learning ecosystem in junior high schools. Through the integration of STEM projects, competitions, STEM Exploration Visits, and STEM Exhibitions in public spaces, students gained a more contextual, collaborative, and meaningful learning experience. This program also demonstrated alignment with Herrington and Oliver's nine elements of authentic learning: authentic context, authentic tasks and activities, access to expert performances, multiple perspectives, collaborative construction of knowledge, reflection, articulation, coaching and scaffolding, and authentic assessment.

The research findings indicate that STEM learning focuses not only on the final product but also on an authentic learning process that involves real-world problem-solving, communication, collaboration, and interaction with the community. The project's theme, based on the Sustainable Development Goals (SDGs), specifically Zero Hunger, provided a relevant, real-life learning context. Furthermore, the campus exploration activities and mall exhibition provided students with hands-on experience learning from experts and presenting innovative solutions to the public.

This program also positively impacts students' 21st-century skills, such as critical thinking, creativity, collaboration, communication, and self-confidence. Thus, the festival-based STEM program has the potential to become an authentic STEM learning model that can be implemented sustainably in schools. Future research can expand the program's implementation at different educational levels and measure its impact on student learning outcomes and skills in greater depth.

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