

Evaluation of Integrated STEM Learning in STEM Institutions Based on Mathematics Learning Processes and Outcomes Using the CIPP Model

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Abstract

This research was carried out at a STEM institution with a focus on evaluating the implementation of STEM Integrated learning. The aim of this research is to evaluate using the CIPP (Context, Input, Process, Product) model for STEM Integrated learning and assess students' learning achievements in the field of mathematics studies, as well as evaluate the effectiveness of the STEM Integrated learning process in STEM institutions. The effectiveness of the learning process is assessed based on the level of achievement of learning objectives that have been set at the beginning of the learning period, namely in all aspects of STEM. This research adopts a qualitative approach using the CIPP model, which allows evaluation of aspects of context, input, process and product to achieve effective learning. Research participants involve students, STEM instructors. Primary data was collected through observation instruments, while secondary data was obtained from documentation and interviews. The results of the research show that the application of Integrated STEM learning in STEM-EC UPI can be categorized as good in the input component but can be categorized as quite good in the context, process and product components. This is due to the less-than-optimal mathematical aspects in the STEM Integrated approach in terms of instructor qualifications and aspect assessment results. mathematics students.

Keywords: CIPP Model, Evaluation, STEM Integrated

Introduction

Entering the 21st century, which is almost three decades old, 21st century competency has become the main focus for increasing human resource capacity in the world, including in Indonesia. The 21st century competencies are divided into three categories, including learning competencies, literacy skills, and life competencies (Bayley, 2022; Liao et al., 2016; Zayyinah et al., 2022a). Learning competency is the main competency for students as a guide to forming students who are competitive and able to solve problems (Puspitarini, 2022). Learning competency included in the 4C, namely creative thinking, critical thinking, communication, and collaboration and is closely related to Higher Order Thinking (HOTS) or a learning process that involves elements of high-level thinking, one of which is analytical thinking. However, the scope of 4C competencies or higher-order thinking has not been achieved by many students because they have not been facilitated through learning approaches that nurture these competencies (Syavarizca, 2021). For example, the studies of Wijaya et al. (2022) and Maqruf et al. (2023) reported that students were not yet optimal in analytical thinking when solving mathematical problems. In this regard, 21st-century learning emphasizes adaptive learning through repeated cycles, which is directly supportive of developing analytical thinking. Adaptive learning implemented through approaches such as project-based learning, inquiry learning, and contextual teaching and learning provides iterative experiences, feedback, and

real-world contexts that encourage students to differentiate, organize, and evaluate information, thereby fostering their analytical thinking skills (Aguayo et al., 2023; Dahal, 2022; Degeng et al., 2021; Liao, 2022; Rukayah et al., 2022; Vicente & Llinares, 2020; Zayyinah et al., 2022b). So, it is possible with adaptive learning that mathematics learning can be more optimal.

Meanwhile, in the 21st century an approach has emerged that is at least in line with adaptive learning, namely STEM learning. STEM is a learning approach that emphasizes the relationship between knowledge and skills in science, technology, engineering, arts and mathematics (Sa'ida, 2021). STEM, which supports 21st-century learning competencies, has been widely promoted for its integrative application across disciplines. Since its initial introduction by the United States National Science Foundation (NSF) in the 1990s, global attention has increasingly focused on implementing practical STEM education (Cheng et al., 2022). In Indonesia, various initiatives and research have also explored both STEM and STEAM-based learning, indicating that these approaches are no longer entirely new in the educational landscape. However, challenges remain in ensuring that STEM/STEAM is integrated deeply into classroom practice with strong connections to mathematics (Lavi et al., 2021). According to Robert and Cantu (2012), there are three approaches to STEM learning, namely separated, embedded, and integrated. The STEM Separated (silo) approach has the principle that in learning, each discipline in STEM is isolated from each other. In STEM Embedded, learning is dominant in one aspect which provides the cultivation of knowledge and skills in other aspects of STEM. In this embedded approach, the implementation of learning is more emphasized on reviewing several contexts, but the material embedded is not designed to be evaluated or assessed. Meanwhile, the STEM Integrated approach in STEM learning is carried out by removing barriers to the four components and making them into subjects (Roberts & Cantu, 2012). The implementation of STEM learning or training in Indonesia generally still uses STEM learning with an integrated approach (Cahyanti et al., 2024; Lafifa et al., 2023; Lidinillah et al., 2019). This meaning of integration is different from embedding it in the embedded approach. Ideally, the integrated use of the four components in STEM allows students to gain mastery of the competencies needed to solve problems or ideally, students' acquisition of competencies in solving problems can be done by integrating the four components in STEM (Harden, 2000). Educators who can teach STEM well will be very useful for students in facing a "multidisciplinary" world so that they will be better trained in solving the problems they will face (Roberts & Cantu, 2012). However, what does the practice of STEM Integrated learning in Indonesia actually look like? While the integrated use of the four components in STEM is expected to enable students to master the competencies needed to solve problems as emphasized by Harden (2000), there is still limited evidence regarding its impact on students' mathematical strength and mathematical abilities. Considering that most STEM initiatives in Indonesia adopt the STEM Integrated model, this study seeks to investigate whether such an approach sustains and enhances students' mastery of mathematics or whether, conversely, it tends to weaken the role of mathematics within STEM learning. To address this issue, the present study was conducted at one of the STEM Centers in Indonesia that implements an integrated STEM approach.

Methods

This research was conducted at one of the STEM Centers in Indonesia that focuses on integrated STEM education. The class used is the STEM-EC training class. This type of evaluation research using the CIPP model is research with a qualitative approach. Stufflebeam stated that the CIPP evaluation model is a comprehensive framework for directing the implementation of formative and summative evaluations of program objects, projects, personnel, products, institutions and systems (Stufflebeam & Coryn, 2014). From the data collected, it is then described in narrative form. Data analysis in qualitative research is a continuous process carried out using non-participatory observation (Creswell, 2014). So, the data analysis method used in this research was carried out throughout the research, starting from initial observations, data collection, the report writing stage to drawing conclusions and then the results were narrated. The analysis method for the instruments created is validation by experts. Evaluation of the Integrated STEM Program using the CIPP Model begins with an assessment by the validators of the instrument based on the indicators contained in the Validation Sheet for each instrument. The assessment on the validation sheet is in the form of scoring from 1-5, with each score having a different indicator of achievement.

The focus of monitoring and evaluation based on the Context-Input-Process-Product monitoring and evaluation stages is stated Stufflebeam & Coryn (2014) as follows:

- Context assessment includes the profile of the educational institution, the background of the educational institution's learning program, geographical-demographic factors, and the socio-economic and educational background of the students' parents. The information collected is used as a basis for program considerations.
- Input assessment includes students, curriculum, teaching materials, and educators and learning facilities. Data collected during the assessment stage is used as a decision maker.
- Process assessment is an assessment activity during the implementation of learning. This assessment is directly related to learning activities, use of learning media, usefulness of the laboratory, and assignment types.
- Product/output assessment, related to the results of program implementation. The assessment is carried out to find out how far the implementation has gone

To facilitate evaluation monitoring, it is necessary to refer to the indicators contained in the context, input, process, and product components of the CIPP model. In this study, the evaluation monitoring adopts the CIPP evaluation instrument developed by Ramadani & Supahar (2017) because its indicators are considered relevant and adaptable to the conditions of the STEM institution under investigation, that is:

Table 1

Source of Data for Evaluation of Integrated STEM Learning Programs

Component Evaluation	Aspect	Indicator	Number Item
Context	Analysis Need	Institutional Background and Readiness	1, 2
		Student Characteristics and Socio-Economic Backgrounds	3, 4

		Assessment System and Learning Needs	5
Inputs	Competence Instructor	Pedagogical Competence	1, 2, 3, 4, 5
		Professional Competency	6
		Personality Competencies	7
		Social Competence	8
		Characteristics Learners	Student Interests
Availability Facilities and Infrastructure	Laboratory Conditions	13, 14, 15	
	Availability of Tools and Material	16, 17	
Process	Planning	Planning Evaluation STEM Integrated	1
	Implementation	Implementation of Integrated STEM Assessment	2, 3, 4
Products	Implementation Results	Accuracy of use of assessment instruments	1
		Skills Improvement	2, 3
		Effectiveness of Implementing STEM Integrated	4

Meanwhile, the rubric used to determine the score for each indicator item is also adapted Ramadani & Supahar (2017). Next, the values and criteria table of the evaluation results of the adopted CIPP model are presented (Tsani et al., 2021)

$$\text{Mark} = \frac{\text{Sum of Score}}{\text{Total of Score}} \times 100\%$$

Table 2
CIPP Model Evaluation Results Criteria

Mark	Category
86% to 100%	Very well
71% to 85%	Good
55% to 70%	Enough
Less than 55%	Not enough

Results and Discussion

The results and discussion in this research are based on the CIPP monitoring and evaluation stages, namely Context-Input-Process-Product (Stufflebeam & Coryn, 2014).

Integrated STEM Learning Program Context Components

Evaluation of the context in the STEM Integrated learning program starts from how the assessment system has been implemented in the STEM institution studied, including how

STEM instructors prepare assessments for the field of mathematics as one aspect of STEM. The research was conducted at one of the STEM Centers in Indonesia that implements an integrated STEM approach in its learning programs. This institution is managed under a university’s center of excellence and serves as a hub for developing and implementing STEM-based educational practices. The number of study groups at the STEM institution is 3 classes, mecatronix class (using coding) with 20 students, creativity class (designing projects) with 10 students, invention class (making coding and using it) with 10 students. The total number of students at the STEM institution is 40 students. Meanwhile, the number of educators or instructors is 5 permanent instructors and 10 assistant instructors, who have a background in science and engineering studies, and there are no instructors with a background in mathematics studies. The physical form of the STEM Center building is suitable for providing education. The rooms in STEM Center are 4 classrooms, 1 STEM Integrated Laboratory which is combined with the instructor room, 1 STEM Center leadership room and a vehicle parking area. Where each classroom has an infocus and projector which really supports the learning process and tools and materials to support STEM practice are available in the laboratory. The following are the results of the CIPP model evaluation on the context component at the STEM Center institution adapted Ramadani & Supahar (2017):

Table 3
Evaluation Results of Context Components in STEM Center

ITEM OF STATEMENT	SCORE
The institution considers the socio-economic backgrounds of students in planning and implementing STEM learning.	3
The institution identifies the socio-economic conditions of instructors as factors that may influence the implementation of STEM Integrated learning.	2
Students’ prior knowledge and experience in STEM-related fields are taken into account before designing learning activities.	3
Instructors’ prior qualifications and understanding of STEM are evaluated to ensure readiness for implementing STEM Integrated learning.	5
The institution analyzes the specific needs and challenges faced by both students and instructors as part of the preparation for STEM learning.	3
Total score	16

$$\begin{aligned} \text{Mark} &= \frac{16}{25} \times 100\% \\ &= 64\% \end{aligned}$$

Based on the scores obtained, STEM-integrated learning at selected STEM Centers in Indonesia falls within the adequate category for the context component. Detailed analysis shows that the limited quality of mathematics assessment is closely related to the academic background of the instructors. Although some instructors come from engineering disciplines that inherently involve mathematics, their expertise lacks the expertise or specialization of

instructors with formal mathematics education. This condition is consistent with previous findings that emphasize the importance of instructor qualifications in ensuring the quality of subject-specific assessment practices. (Antony et al., 2019; Sebastian & Periyathamby, 2020).

Integrated STEM Learning Program Input Components

The input aspects presented in this evaluation research include instructor competency, student characteristics, and availability of infrastructure. At the STEM Center studied, there are 15 permanent instructors, consisting of 10 from science fields and 5 from electrical engineering. None of the instructors have a formal background in mathematics. Their teaching experience ranges from a minimum of 1 year to a maximum of 2 years, with relatively similar exposure to training or upgrading activities related to learning materials and STEM assessment systems over the past two years. However, none of the subject instructors have participated in training programs on learning materials, assessment systems, or STEM practice guidelines provided by external experts or institutions outside the STEM Center itself. Meanwhile, there are 40 students enrolled at the institution during the 2022/2023 academic year.

In terms of infrastructure, monitoring results show that the learning spaces used are centralized in a Center of Excellence (CoE) building. All classrooms are equipped with projectors, infocus, and STEM practice tools and materials, making the facilities sufficient and suitable for both study and practice. The available laboratory is an Integrated STEM laboratory, which is shared with the instructors' room. Evaluation results indicate that the laboratory is actively used to support STEM-Integrated learning, as reflected in the schedule and records of item usage and borrowing.

The following are the results of the evaluation of the CIPP model on the input components at the STEM institution adapted Ramadani & Supahar (2017):

Table 4
Evaluation Results of Input Components in STEM Center

ITEM OF STATEMENT	SCORE
Instructor Competency	
The instructor prepares and utilizes STEM Integrated learning tools appropriately eg provides lesson plan and practice materials aligned with objectives.	3
The instructor opens the learning activities effectively eg greets students and links lesson with prior knowledge.	5
The instructor implements core learning activities systematically eg facilitates inquiry and group problem solving.	5
The instructor closes the learning activities meaningfully eg summarizes key points and gives follow up tasks.	5
The instructor assesses student learning outcomes with varied techniques eg uses written tasks and performance-based assessment.	3
The instructor conveys mathematics content accurately and contextually eg explains concepts clearly and relates them to STEM applications.	1
The instructor demonstrates professional personality traits eg shows discipline and fairness in guiding students.	5

The instructor communicates with students clearly and interactively eg uses simple language and encourages participation.	5
Learner Characteristics	
Students are active during learning	4
Students are interested in exploring information from various learning sources	3
Students show good performance during the learning process	5
Students demonstrate collaborative skills in group work by contributing ideas based on prior knowledge, showing motivation to participate, and respecting socio-cultural differences	5
Availability of Facilities and Infrastructure	
The condition of the laboratory room is clean and comfortable	5
The property in the laboratory is well arranged	5
Complete practicum supporting facilities are available	5
The practical equipment needed for STEM Integrated experiments is completely available in the laboratory	5
Practical materials needed for STEM Integrated experiments are completely available in the laboratory	5
Total score	72

$$\begin{aligned} \text{Mark} &= \frac{72}{85} \times 100\% \\ &= 85\% \end{aligned}$$

Based on the scores obtained, STEM Integrated learning at STEM Center in the input component is in the good category. We can see this in detail about the value that really supports adequate facilities and infrastructure even though the characteristics of students are not yet fully active, especially in their curiosity about the mathematical aspects of STEM Integrated. Meanwhile, the instructor's competency is still at a low score, especially in delivering material in the field of mathematics in the STEM Integrated process. This is in line with several studies regarding the importance of the qualifications of educators or instructors in teaching a subject area (Lavery et al., 2017; Sebastian & Periyathamby, 2020).

Integrated STEM Learning Program Process Components

The process components in the CIPP model evaluation in this research include planning and implementing STEM learning assessments. Planning and implementation of assessments at STEM Center is carried out by instructors who are monitored by STEM leaders. The planning and implementation of the assessment includes assessing all aspects of STEM and the researchers specifically focus on one aspect, namely the mathematics aspect. The following are the results of the CIPP model evaluation on the process components at the STEM Center institution adapted Ramadani & Supahar (2017):

Table 5

Results of Evaluation of Process Components in STEM Center

ITEM OF STATEMENT	SCORE
The instructor prepares the application of the STEM Integrated assessment instrument in the learning process well	4
The instructor measured all four aspects of STEM Integrated skills well	4
The instructor completes the STEM Integrated assessment instrument properly	4
The instructor carries out an assessment of the mathematics subject area during the learning process	2
Total score	14

$$\begin{aligned} \text{Mark} &= \frac{14}{20} \times 100\% \\ &= 70\% \end{aligned}$$

Based on the evaluation results, STEM-Integrated learning at the selected STEM Center in Indonesia is categorized as sufficient in the process component. This conclusion is not only drawn from the scores obtained but also from observation notes and field documentation during the implementation of STEM training. The notes show that the assessment of the mathematics subject area within the STEM-Integrated learning process is still limited, as instructors encounter challenges in designing and applying appropriate assessment strategies. This is in line with several studies regarding the inability of an educator or instructor to carry out assessments if it is not appropriate to the field of study, they master (Casian et al., 2021; Lee & Lee, 2020)

Integrated STEM Learning Program Product Components

The product/output aspects presented in the results of this research include the accuracy of using assessment instruments, improving students' skills, and the effectiveness of implementing STEM Integrated. Effectiveness can be seen from student learning outcomes and can be reviewed from every aspect of STEM. The following are the results of the CIPP model evaluation on the process components at the STEM Center institution adapted Ramadani & Supahar (2017):

Table 6

Product Component Evaluation Results at STEM Center

ITEM OF STATEMENT	SCORE
Assessment instruments are used to measure STEM Integrated skills properly and precisely	4
Implementation of STEM Integrated assessment improves students' cognitive mathematics learning outcomes	2
Implementation of the STEM Integrated assessment improves students' mathematics skills at each meeting	2

All students in one class are well observed by the instructor through the STEM Integrated assessment 5

Total score	13
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$$\begin{aligned} \text{Mark} &= \frac{13}{20} \times 100\% \\ &= 65\% \end{aligned}$$

Based on the evaluation, STEM-Integrated learning at the selected STEM Center in Indonesia on the product component falls into the sufficient category. This result indicates that the implementation of assessments within the STEM-Integrated framework has not yet led to significant improvement in students' learning outcomes, particularly in the mathematics domain. Such findings point to a broader issue often raised in educational research that integration across STEM fields, while beneficial for fostering problem-solving and creativity, can inadvertently weaken the depth of understanding in one specific discipline if not carefully balanced (Li & Schoenfeld, 2019). In this context, the mathematics component appears less developed compared to science or engineering, which raises questions about the design of integrated assessments and the expertise of instructors involved. From a practical perspective, this suggests the need to strengthen mathematics-focused assessment strategies within STEM learning to ensure that students not only engage in interdisciplinary tasks but also build solid conceptual foundations in mathematics. These findings align with prior studies reporting that mathematics, when insufficiently emphasized in integrated STEM approaches, often results in less-than-optimal knowledge development among students. Expanding this discussion within broader educational frameworks highlights the importance of professional development for instructors, the refinement of integrated curricula, and the alignment of assessment practices with both disciplinary depth and interdisciplinary goals (Miqdadi & Al-Jamal, 2013).

Conclusion

The application of STEM-Integrated learning at the STEM Center under study shows varied results across different components. Based on the findings, the context, process, and product components fall into the sufficient category, while the input component demonstrates stronger results, particularly in terms of supporting facilities and infrastructure. However, some limitations were also identified, especially regarding the qualifications of instructors, as there are currently no instructors with a background in mathematics. This condition appears to influence the extent to which mathematical aspects are addressed in the implementation of STEM-Integrated learning. In addition, student learning outcomes in mathematics have not shown significant improvement, suggesting that the integration approach may require further refinement. Taken together, these findings point to both strengths and areas for development in the current implementation, particularly in balancing interdisciplinary integration with sufficient attention to mathematics.

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