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

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a b s t r a c t

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 using the CIPP model 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.

K e y w o r d s :
Evaluation; CIPP Model; 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. 21st century competencies are divided into three categories, including learning competencies, literacy skills, and life competencies. 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 high level thinking has not been achieved by many students because students have not been facilitated in learning approaches that support these competencies as in the research of Wijaya et al. (2022) and Maqruf et al. (2023) who obtained the results that students were not optimal in analytical thinking in solving mathematical problems. Meanwhile, 21st century learning emphasizes adaptive learning using repeated cycles, which is in line with project-based learning, inquiry learning and contextual teaching learning (Aguayo et al., 2023; Dahal, 2022; Degeng et al., 2021; Liao, 2022; Rukayah, Daryanto et al., 2022; Vicente & Llinares, 2020; Zayyinah et al., 2022). So it is possible with this learning model that mathematics learning can be more optimal.

Meanwhile, in the 21st century an approach has emerged that is at least in line with these learning models, namely STEAM learning. STEAM is a learning approach that emphasizes the relationship between knowledge and skills in science, technology, engineering, arts and mathematics (Sa'ida, 2021). STEAM, which supports 21st century learning competencies, has been widely developed for integrative application between its constituents, but has not been widely developed in Indonesia. Initially, there was only a STEM approach introduced by the United States National Science Foundation (NSF) in the 1990s. Much global attention has been given to integrating practical STEM education (Cheng et al., 2022). The arts can serve as a springboard for infusing traditionally taught STEM subjects with the kind of creative thinking that drives innovation. STEAM will help advance STEM teaching and even improve pedagogy in general, moving Learners towards more creative and innovative ways of thinking (Stewart 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 (embedded) learning, 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. 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). But what is the STEM Integrated learning process actually like in Indonesia? Does the integrated use of the four components in STEM enable students to gain mastery of the competencies needed to solve problems as stated by Harden (2000)? To answer this question, researchers are interested in conducting research at one of the STEM institutions at one of the universities in Indonesia.

METHODS

Population and Sample

This research was carried out at the STEM-EC (Science, Technology, Engineering, Mathematics – Education Creativity) Institute at the Indonesian University of Education (UPI). The class used is the UPI STEM-EC training class.

Reseach Design

This type of evaluation research using the CIPP model is research with a qualitative approach. The CIPP evaluation model was developed by Daniel Stufflebeam in 1966. 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. From the data collected, it is then described in narrative form. Miles and Huberman (1994) said that data analysis in qualitative research is a continuous process carried out using non-participatory observation. 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 validator 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.

Frame Work Flow

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 look at the indicators contained in the context, input, process and output used in this evaluation monitoring adapting the CIPP model evaluation instrument Ramadani & Supahar (2017), that is:

Table 1.
Source of Data for Evaluation of Integrated STEM Learning Programs

Component Evaluation	**Aspect**	**Indicator**	**Number Item**
Context	Analysis Need	The assessment system that has been implemented	1, 2, 3, 4, 5
Inputs	Competence Instructor	Pedagogical Competence	1, 2, 3, 4, 5
		Professional Competency	6
		Personality Competencies	7
		Social Competence	8
	Characteristics Learners	Student Interests	9, 10, 11, 12
	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

RESULT 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 institutions studied, including how STEM instructors prepare assessments for the field of mathematics study as one aspect of STEM. The STEM institution studied is STEM-EC UPI which is located on Jl. Dr. Setiabudi No. 229, Isola Village, Sukasari District, Bandung City. STEM-EC UPI is under the auspices of the UPI Center of Excellence. 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 UPI STEM-EC building is suitable for providing education. The rooms in STEM-EC UPI are 4 classrooms, 1 STEM Integrated Laboratory which is combined with the instructor room, 1 STEM-EC UPI 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 UPI STEM-EC institution adapted Ramadani & Supahar (2017):

Table 3
Evaluation Results of Context Components in STEM-EC UPI

ITEM OF STATEMENT	SCORE
The instructor carries out assessments during the learning process	3
The instructor applies several assessment techniques in the field of mathematics during learning	2
Instructors assess all aspects of student learning outcomes during learning	3
Instructors measure several students' skills during STEM Integrated learning	5
Instructors apply the principles of authentic assessment in learning	3
Total score	**16**

$$\text{Mark} = \frac{16}{25} \times 100\%$$

$$= 64\%$$

Based on the scores obtained, STEM Integrated learning at STEM-EC UPI in the context component is in the sufficient category. We can see this in detail about the lack of grades in the application of assessments for the field of mathematics study due to instructor limitations. This is in line with several studies regarding the importance of the qualifications of educators or instructors in assessing a subject area(Antony et al., 2019; Antony & Elangkumaran, 2020).

Integrated STEM Learning Program Input Components

The input aspects presented in this evaluation research include instructor competency, student characteristics, and availability of infrastructure. Permanent instructor The UPI STEM-EC consists of 15 instructors, while there are 10 instructors in the science study field and 5 instructors in the electrical engineering study field. There are no instructors with a background in mathematics. The instructor's teaching experience varies, minimum 1 year and maximum 2 years and has almost the same experience following training/upgrading related to learning materials and STEM assessment systems for the last 2 years. All subject instructors have never attended training courses on learning materials, learning assessments and STEM practice guidelines from expert parties or institutions outside STEM-EC UPI. Meanwhile, there are 40 students taking education at STEM-EC UPI for the 2023/2024 academic year. Furthermore, monitoring results show that the learning space used by STEM-EC UPI as a whole is the CoE building or Center of Excellence UPI (100%). All classes have been installed with infocus and projectors as well as STEM practice tools and materials so that the availability of study and practice space along with the infrastructure is sufficient and suitable for use. Meanwhile, the availability of laboratories at STEM-EC UPI in question is the STEM Integrated laboratory which is combined with the instructor's room. The evaluation results show that the existence of the laboratory is used to support STEM Integrated learning , as evidenced by the schedule and data on the use/borrowing of items in the laboratory.

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

Table 4
Evaluation Results of Input Components in STEM-EC UPI

ITEM OF STATEMENT	SCORE
Instructor Competency	
related STEM Integrated learning tools properly	3
The instructor opened the learning activities well	5
The instructor carries out the core activities well	5
The instructor closed the learning activities well	5

ITEM OF STATEMENT	SCORE
Instructors assess student learning outcomes well	3
The instructor conveys mathematics study material in the STEM Integrated process well	1
The instructor has good personality traits	5
The instructor is able to communicate with students well	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 are able to work together in groups	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**

$$\text{Mark} = \frac{72}{85} \times 100\%$$

$$= 85\%$$

Based on the scores obtained, STEM Integrated learning at STEM-EC UPI 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.

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-EC UPI 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 UPI STEM-EC institution adapted Ramadani & Supahar (2017):

Table 5
Results of Evaluation of Process Components in STEM-EC UPI

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**

$$\text{Mark} = \frac{14}{20} \times 100\%$$

$$= 70\%$$

Based on the scores obtained, STEM Integrated learning at STEM-EC UPI in the process component is in the sufficient category. We can see this in detail about the grades that are still lacking when the instructor assesses the mathematics subject area during the STEM Integrated learning process . 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 UPI STEM-EC institution adapted Ramadani & Supahar (2017):

Table 6
Product Component Evaluation Results at STEM-EC UPI

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**

$$\text{Mark} = \frac{13}{20} \times 100\%$$

$$= 65\%$$

Based on the scores obtained, STEM Integrated learning at STEM-EC UPI on product components is in the sufficient category. We can see this in detail about the scores that are still lacking in the implementation of STEM Integrated assessments which have not improved student learning outcomes in the mathematics aspect. This is in line with research regarding the limitations of integrated STEM aspects that will provide a good and effective understanding of one aspect of STEM (Li & Schoenfeld, 2019). Meanwhile, there is also research which states that mathematics which is integrated with other topics results in less, than optimal student knowledge, especially in mathematics (Miqdadi & Al-Jamal, 2013).

CONCLUSION AND IMPLICATION

Conclusion

The application of STEM Integrated learning in STEM-EC UPI can be categorized as sufficient if seen from the context, process and product components. Furthermore, the application of STEM Integrated learning in STEM-EC UPI can be categorized well in the input component. The advantage lies in the supporting facilities and infrastructure, while the weakness lies in the instructors who do not meet the qualifications for all aspects of STEM because there are no instructors in the field of mathematics studies. Meanwhile, the approach used, namely STEM Integrated, can also be said to have not been effective

in improving students' mathematical abilities, which can be seen from the students' learning outcomes in the mathematical aspect.

Implication

The process of implementing STEM learning is largely determined by the regularity of learning planning, both carried out by the instructor and in terms of the learning approach. The research results show a lack of effectiveness in the mathematical aspect. Therefore, it is necessary to hold a special activity as an effort to increase the instructor's understanding of the STEM learning process and the learning approach which might be changed to an embedded approach. So future research should explore whether the embedded approach is more effective in improving the skills of each aspect of STEM that students are interested in.

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