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ENHANCING ELECTRICAL AUTOMOTIVE PROJECT DESIGN SKILLS WITH A CONTEXTUAL APPROACH

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Abstract

Learning innovations integrating the latest scientific theory sources emphasize the importance of students' technical skills in facing the transformation of Industry 4.0 technology. This study aims to determine the improvement of technical skills with the SAM (Successive Approximation Model) instructional design approach in Automotive Electrical and Electronics Engineering (AEEE) courses based on Industry 4.0. In this study, 20 respondents were divided into three groups. The SAM model is used as a practical learning instruction. The study results show that the SAM instructional design can improve students' abilities in analyzing, thinking critically, and solving problems. However, soft skills are obstacles, such as communication, action, and Emotional management skills. Student demographic data and pretest data compared to satisfaction data show a significant increase. Thus, the SAM instructional design is effective as one of the strategies for improving students' technical skills. This implication can reference more structured and directed skill passport learning.

INTRODUCTION

Technical skills are essential for success in the workplace (Luengo-Aravena *et al.*, 2024). However, these technical skills must be acquired after adequate academic education and technical training (Wragg *et al.*, 2023). However, there is a growing concern that the rapid pace of technological change may outpace the ability of educational institutions to prepare graduates with attributes that apply to the workplace (Tan, Chew and Kalavally, 2017).

In principle, the skills possessed by students can be identified into three, namely: (a) skills for career development, (b) skills in innovating in learning, and (c) having media and technology mastery skills (Stork, 2020). As time passes in the 21st century, students' skills still need to be improved to critical and creative abilities for solving problems from a case. Therefore, educators are needed to strengthen learning (Mutohhari *et al.*, 2021). This effort is carried out by universities to improve student skills through the role of educators through innovation in learning (Moraes *et al.*, 2023).

Types of learning innovation in Higher Education require lecturers to use innovative methods, the latest learning tools, and sources of scientific theory in the learning process (Juškevičienė *et al.*, 2022). Regardless of discipline, innovative teaching can generate interest and motivation for students (Hashim *et al.*, 2019). This reality encourages lecturers to carry out innovative teaching, which is a challenge because they have a dual role as teachers and researchers (Rafsanjani *et al.*, 2021).

Thus, this learning can be declared innovative if it improves students' achievements and technical skills (Djatmika, 2023). Given the workforce's changing needs, it is very important to integrate technological advances, such as artificial intelligence, automation, and data analysis, into teaching methods (Muzuva, 2024).

The SAM (Successive Approximation Model) instructional design can support the integration of technological advances in learning because this model supports the integration of digital technology, which is very important in modern vocational education and training (SZABO, 2022). This need is in line with the demand for talent in the world of work, which continues to change under the background of the intelligent industrial revolution (Yang, Junjie and Weihua, 2023).

Our actions aim to facilitate students' transformation of R.I. 4.0 technology into learning Automotive Electrical and Electronics Engineering (AEEE). This study aims to determine whether the SAM (Successive Approximation Model) instructional design approach improves learning process results.

METHODOLOGY

Research Design

This study aims to explore the skills of Automotive Engineering Education Study Program students in developing prototype product engineering for the Internet of Vehicles (IoV) in the Automotive Electrical and Electronics Engineering (AEEE) course class. The SAM (Successive Approximation Model) instructional design developed by Allen is an effective strategy for creating time-efficient designs.

This process consists of three stages, namely: (1) observation, (2) evaluation, and (3) design, as can be seen in Figure 1 (Roth *et al.*, 2016).

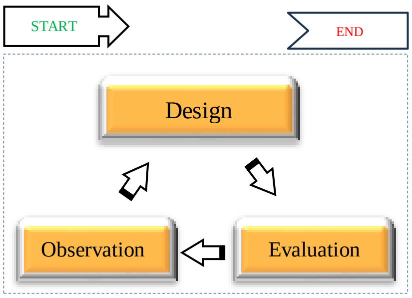


Figure 1. Instructional Design Successive Approximation Model (SAM) (Roth *et al.*, 2016)

The SAM syntax adjusts the objectives and learning outcomes in the Automotive Electrical and Electronics Engineering (AEEE) course according to the needs of graduates of the Study Program, but in the formulation, it is guided by the Decree of the Minister of Manpower Number 167 of 2019 in the Automotive Engineering Field, Subsector of the Autotronic Engineering Field, as seen in Table 1. The SAM syntax in AEEE learning is written using a case method and a team-based project approach. This scheme consists of 16 meetings, which are divided into synchronous and asynchronous meetings, and has been described in the form of a flowchart, as seen in Figure 2.

Table 1. Objectives and learning outcomes of the Automotive Electrical and Electronics Engineering (AEEE) course

Purpose	Learning Outcomes
1. Understand the electrical and electronic systems in vehicles	1. Students understand various electrical systems in vehicles, such as ignition systems, lighting systems, charging systems, control systems (ECU), and CSIT systems
2. Be able to read and interpret circuit schematics	2. Students can read and understand electrical and electronic circuit schematics in automotive vehicle systems
3. Use related equipment and technology to develop troubleshooting skills	3. Students can master the use of diagnostic tools such as multimeters, oscilloscopes, and scan tools as a medium for solving problems effectively, including analysis of the cause of the problem and implementation of the right solution
4. Analyze and repair automotive electronic systems	4. Students are expected to be able to analyze and repair automotive electronic systems with good testing
5. Develop critical and analytical thinking skills in designing and developing new technology systems	5. Students are expected to develop critical and analytical thinking skills to solve problems, enabling them to design and develop new and innovative automotive electronic systems, such as the latest technological developments in automotive electrical and electronic systems, ignition systems, lighting systems, charging systems, control systems (ECU), and CSIT systems

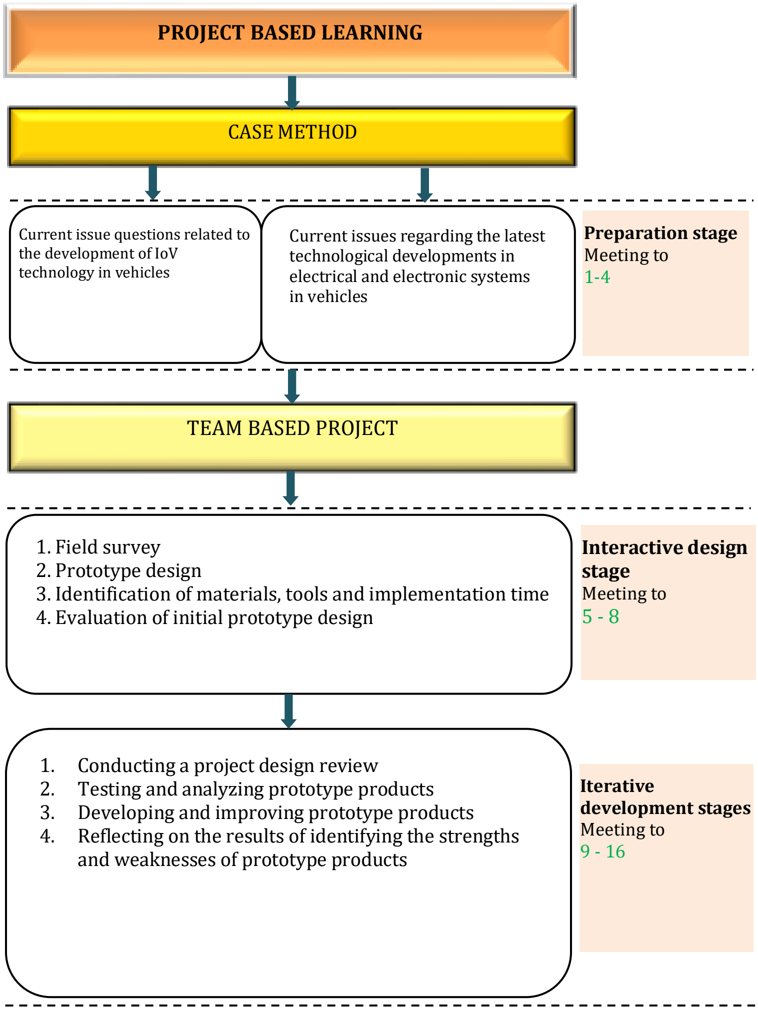


Figure 2. Flowchart of the syntax for learning the AEEE course using the case method and team-based project approaches

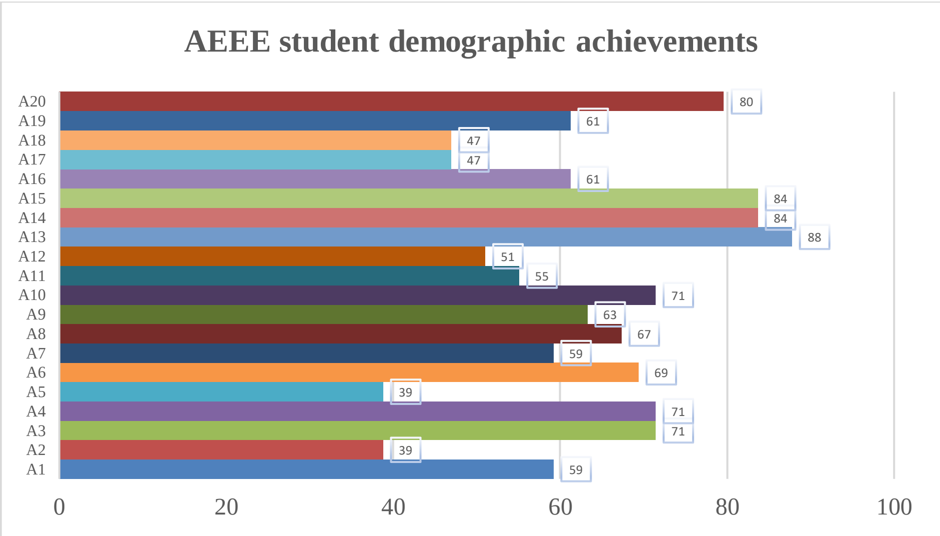
Participant

The following is a technique for identifying the demographic level of students in achieving Automotive Electrical and Electronics Engineering (AEEE) knowledge based on learning objectives and achievements (Hansson and Ekenberg, 2017). This action aims to homogenize the distribution of students in study groups; this screening is divided into four levels, namely very high (achievement> 85), high (achievement> 75), moderate (achievement> 65), and low (achievement <65). The form of visual data was obtained from the responses of 20 students who were members of the Automotive Electrical and Electronics Engineering (AEEE) course before being given the subject matter.

Data analysis was obtained using a Likert scale on an interpretation score of 1-7. Indicators that measure the demographics of student knowledge achievement can be seen in Table 2, and the demographic results in Figure 3.

Table 2. Demographic indicators and student satisfaction

Student demographics		
Indicator	**Level**	**Assessment criteria**
Learning Objectives (A.1.1)	Very High	I very clearly understand the learning objectives
	Low	I do not understand the learning objectives
Suitability of Objectives to Needs (B.1.1)	Very High	My ability level is very appropriate for this learning outcome
	Low	My ability level is not appropriate for this learning outcome
Suitability of Achievements to Abilities (B.1.2)	Very High	My confidence in understanding the material to be achieved in this learning is very high
	Low	My confidence in understanding the material to be achieved in this learning could be much higher
Belief in Achieving Goals through Activities (C.1.1)	Very High	The learning outcomes are very much in line with the competency aspects that we want to achieve, in my opinion
	Low	The learning outcomes do not align with the competency aspects that we want to achieve, in my opinion
Achievement by All Students (C.1.2)	Very High	This learning outcome can be achieved within the given time
	Low	I am not confident that this learning outcome can be achieved within the time given
Completeness of Learning Achievements (D.1.1)	Very High	The material to be studied is obvious
	Low	The material to be studied is not clear
Identification of Learning Needs (E.1.1)	Very High	I want this learning to improve my automotive electrical product design skills
	Low	I don't want to learn this because it doesn't improve my automotive electrical product design skills
Student satisfaction		
Satisfaction with learning outcomes (A.4.1)	Very High	This activity is perfect for fulfilling my skills
	Low	This activity cannot fulfill my skills
Additional learning needs that have not been met (B.4.1)	Very High	Learning needs have been met through this practical learning
	Low	I really need additional learning after this because it has not been met through this practice
Level of involvement in learning activities (C.4.1)	Very High	I am very actively involved in every learning activity
	Low	I am not actively involved in every learning activity
Improved problem-solving skills (D.4.1)	Very High	This learning helps me improve my problem-solving skills
	Low	This learning does not help me in improving my problem-solving skills
Quality of feedback received (E.4.1)	Very High	The lecturer's feedback on every activity that I have done in this learning is very useful
	Low	The lecturer's feedback on every activity that I have done in this learning is not useful
Quality of support facilities and infrastructure (F.4.1)	Very High	Support for facilities and infrastructure is conducive during this learning
	Low	Support for facilities and infrastructure is not helpful during this learning



Very High	1
High	3
Medium	5
Low	11

Figure 3. AEEE learning attainment levels

Based on Figure 3, the distribution of student groups is shown in Table 3 as follows:

Table 3. Distribution of student study groups

Group member	Student name
Group 1	A13,A10,A8,A19,A1,A18
Group 2	A14,A4,A6,A16,A11,A17,A20
Group 3	A15,A3,A9,A7,A12,A2,A5

Data Collection

There are three stages in the SAM instructional design. The first stage is observation, where participants answer questions on the field observation worksheet. This stage aims to collect detailed empirical data about the phenomena needed to solve the problem. The data is then poured into the initial design of the prototype product, which consists of several components, such as the initial design of the prototype product (wiring diagram), findings from observations, implementation time, and identification of materials and costs needed.

The second stage is to present the results of field observations to evaluate the content of the hardware and software findings that will be implemented, the initial design of the CSIT prototype product production flowchart, the materials and tools needed, and details of the implementation time and documentation photos. After the presentation, the initial design of the prototype product in the form of a working drawing layout and wiring diagram can be made. The product layout image for mechanical design and wiring diagrams uses CAD or Fritzing software.

The third stage is to carry out the prototype product design process for each study group by referring to the flowchart. At this stage, it is possible to conduct re-observations to refine the information written in the previous stage. Furthermore, students test the prototype product to the lecturer for evaluation and analysis. At this stage, the CSIT prototype product based on the IoV that has been completed is tested for functionality to determine the strengths and weaknesses of the product. Based on the testing and evaluation results, the prototype product is then improved. After the product is completed, students are asked to evaluate the achievement of learning outcomes and measure student satisfaction after being given the subject matter.

Table 4. Student achievement levels

Indicator	Level	Assessment criteria	Point
Initial Product Design Assessment			
Analytical skills (A.2.1)	Very High	Students can identify project ideas they want to work on based on observation data	20
	Low	Students need help identifying project ideas they want to work on based on observation data	
Communication skills (B.2.1)	Very High	Students can work together in teams	30
	Low	Students are not able to work together in teams	
Critical thinking skill (B.2.2)	Very High	Students can solve problems found in the project	30
	Low	Students are not able to solve problems found in the project	
Presentation skills (B.2.3)	Very High	Students can present findings as a project plan	10
	Low	Students are not able to present findings as a project plan	
Reflection skills (C.2.1)	Very High	Students make detailed project improvement and development plans	10
	Low	Students do not make detailed project improvement and development plans	
Final Evaluation			
Problem Solving Skills (A.3.1)	Very High	Able to identify problems faced in guided projects	15
	Low	Not able to identify problems faced in guided projects	
Design and development skills (B.3.1)	Very High	Able to create compelling designs for prototype projects and able to develop innovative solutions	40
	Low	Not able to create compelling designs for prototype projects and develop innovative solution	
Technology usage skills (B.3.2)	Very High	Able to use appropriate hardware and software	25
	Low	Not able to use appropriate hardware and software	
Project management skills C.3.1)	Very High	Able to manage time and available resources	10
	Low	Unable to manage time and available resources	
Writing skillsn (C.3.2)	Very High	Able to write clear and compelling reports	10
	Low	Unable to write clear and compelling reports	

Data Analysis

Three stages will be analyzed. In the observation stage, the author collects data in the form of qualitative descriptions to reveal meaning by describing facts (Yağmur, Demirel and Kılıç, 2024). The results are in Table 5, a content analysis written on the observation results sheet. The findings obtained include findings of hardware and software to be applied, the initial design of the CSIT prototype product production flowchart, materials and costs needed, implementation time, and documentation photos.

The second stage is to conduct guided design by providing feedback to students based on the initial product design assessment data from field observations, which can be seen in Figure 4. The purpose of this stage is to determine the strengths and challenges of the initial product design results from the student's perspective so that they can decide on the right product layout design (Huber *et al.*, 2023); the results can be seen in Figure 5.

The third stage is to conduct an assessment during the product design process. At this stage, the assessment is obtained through the lecturer's observation sheet during the product design process using quantitative descriptive techniques. Feedback is also carried out weekly; in this process, participants can re-observe to achieve product perfection (Stige *et al.*, 2024). According to (Gunarathna *et al.*, 2024), after the target is achieved, some feedback is needed to complete the project. First, feedback should be given about the project results. If the product has to be tested for performance and errors, it must be corrected accordingly. This can be done effectively through product demonstrations to fellow students and lecturers using quantitative descriptive techniques; the final evaluation results are shown in Figure 6. Next, after the product is completed, students are asked to evaluate whether the focus of teaching/learning has been achieved and the project results have been completed by comparing student demographic data. The results can be seen in Figure 7 and Table 6.

RESULTS AND DISCUSSION

Observation

Table 5. Field observation results

Group members	Findings	Development CSIT	Material	Cost	Time (week)	Documentation
Group 1	Mitsubishi Pajero Sport	Back Door (open/close) System	Node MCU ESP8266	38.000	16	
			Cable jumper	12.000		
			Acrylic	33.000		
			Motor Servo	16.000		
			Switch push button	8.000		
			Smartphone	free of charge		
			Sensor Voice	8.000		
Group 2	Toyota Avanza Veloz	Lighting Control System	Arduino Uno R3	95.000	16	
			Cable jumper	23.000		
			Acrylic	10.000		
			Sensor LDR	5.000		
			LED Lights	36.000		
			4 channel relay	32.000		
			Rain sensor	7.000		
Group 3	Toyota Calya	Lighting Control System (up/down)	Arduino Uno R3	95.000	16	
			Cable jumper	15.000		
			Acrylic	55.000		
			Sensor Gyro MPU6050	26.000		
			Roda	24.000		
			12V/DC Lamp	10.000		
			2 channel relay	25.000		

Group 1 has presented the results of observations on the Mitsubishi Pajero Sport car, which has implemented semi-automatic back door technology. This technology is operated by a switch on the steering wheel and a push button on the bottom of the back door. Therefore, in this study, it is necessary to develop a prototype of the Back Door (open/close) System based on IoV, with material specifications and costs that can be seen in Table 5.

Group 2 presented the results of observations on the Toyota Avanza Veloz car, which did not implement the lighting control system (LCS) technology. This finding is interesting to be developed into a prototype. This system is a bright lamp that can control the headlights based on environmental conditions, such as day and night and when no other vehicles are in front. The specifications of materials and costs can be seen in Table 5.

Group 3 presented the results of observations on the Toyota Calya car, which did not implement the lighting control system technology (up/down). This finding is interesting to be developed into a prototype. This system is a bright lamp that can control the lighting on the headlights when the vehicle is on a track with an angle of elevation above 30 degrees. The specifications of materials and costs can be seen in Table 5.

The results of field observations can provide students with further experience to explore new skills they want to develop (Stork, 2020). However, weak communication skills during observations are a limitation in obtaining data during observations (Mutohhari *et al.*, 2021).

Design

1. The initial design was conducted at the seventh and eighth-week meetings in three AEEE study groups. This treatment obtained assessment results in each study group, as seen in Figure 4.

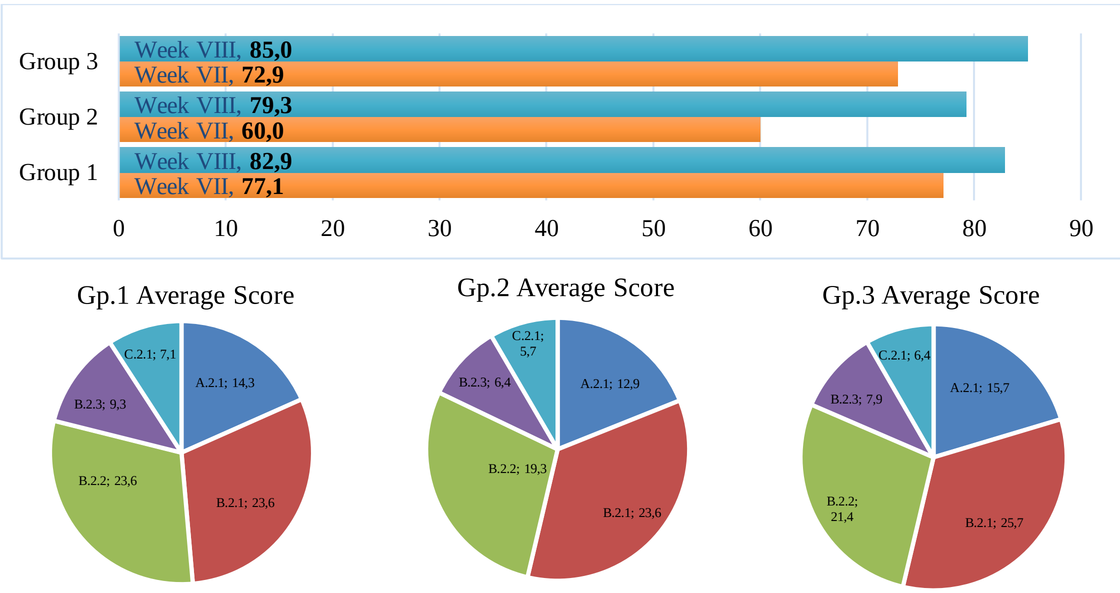


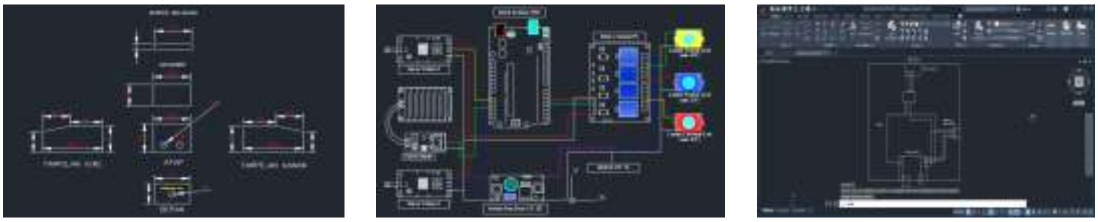
Figure 4. Initial product design assessment

The results of this initial evaluation are divided into four levels, namely very high (achievement >85), high (achievement >75), moderate (achievement >65), and low (achievement <65). Figure 4 shows that Group 1 obtained a score of 77.1 at the seventh-week meeting and increased by 5.9 at the eighth meeting, thus obtaining the 'high' criteria. Group 2 obtained a score of 60.0 at the seventh meeting and increased by 19.3 at the eighth meeting, thus obtaining the 'moderate' criteria. Meanwhile, Group 3 obtained a score of 72.9 and increased by 12.1 at the eighth meeting, thus obtaining the 'high' criteria.

Based on the initial product evaluation analysis results, Group 2 showed significant improvement when evaluated weekly due to major errors that had to be fixed immediately. On the other hand, Group 1 experienced insignificant improvement because the fixes that had to be completed were only minor errors. Support for observation experiences provides full student involvement in layout design in project-based learning (Viswambaran and Shafeek, 2019). However, ability, capacity and clarity of roles hinder participants from developing their technical skills (Goldman *et al.*, 2020).

2. Product layout design

   The initial design of the prototype product is presented as a working drawing layout and wiring diagram. The product layout design is made using CAD or Fritzing software; the results are as follows:



Group 1 Group 2 Group 3

Figure 5. Initial design layout of each group

Evaluation

1. The final evaluation was conducted in the 9th to 16th week in three AEEE study groups. As seen in Figure 3 below, the assessment results for each study group are as follows:

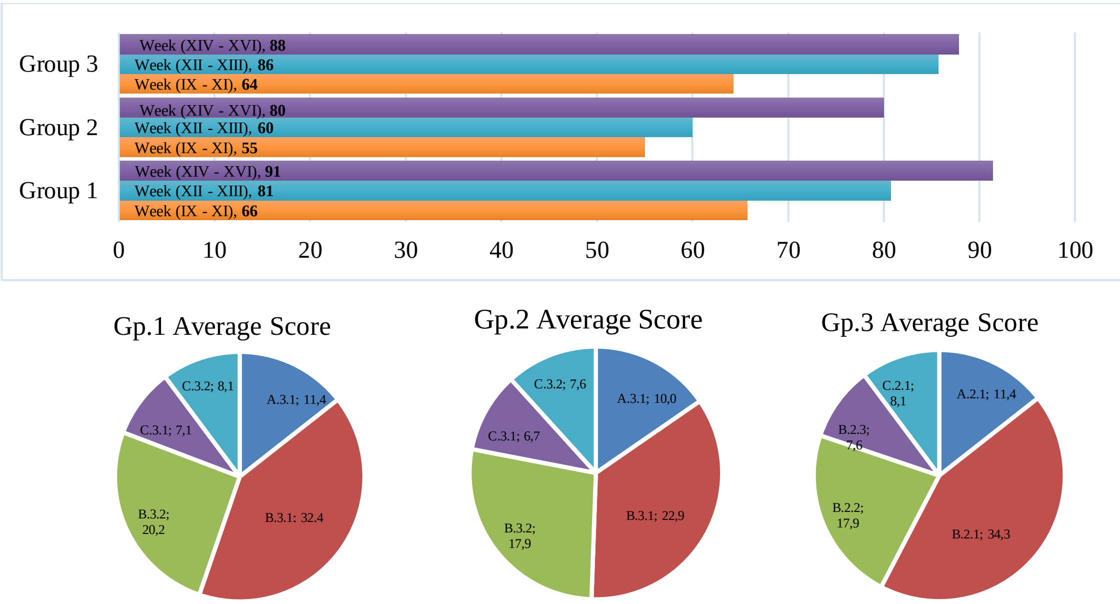


Figure 6. Final evaluation

Figure 4 above shows the results of the final evaluation of this learning, which is divided into three stages of activity as follows:

Phase 1 (weeks 9-11): Each study group obtained a score of <70, which is very low. This is due to my problem-solving ability and skills in project management, which still need to improve.

Phase 2 (weeks 12-13): Group 1's score increased to 81.0, group 3's score increased to 86.0, and group 2's score remained low at 60.0. The low achievement in group 2 was due to the need for more project design and development skills.

Phase 3 (weeks 14-16): Each study group obtained an increase in score >80. However, group 2 was still hampered by the low product design skills of students.

Problem-solving and critical thinking skills provide significant benefits for reasonable provisions for higher education students in entering the world of work (McCormick, Clark and Raines, 2015), but students' low emotional intelligence hampers this situation in solving problems in group learning (Cesur, 2020).

2. Learning outcomes are evaluated from the responses of students participating in the lecture, which aims to measure student satisfaction after the subject matter is presented. The results can be seen in Figure 5.

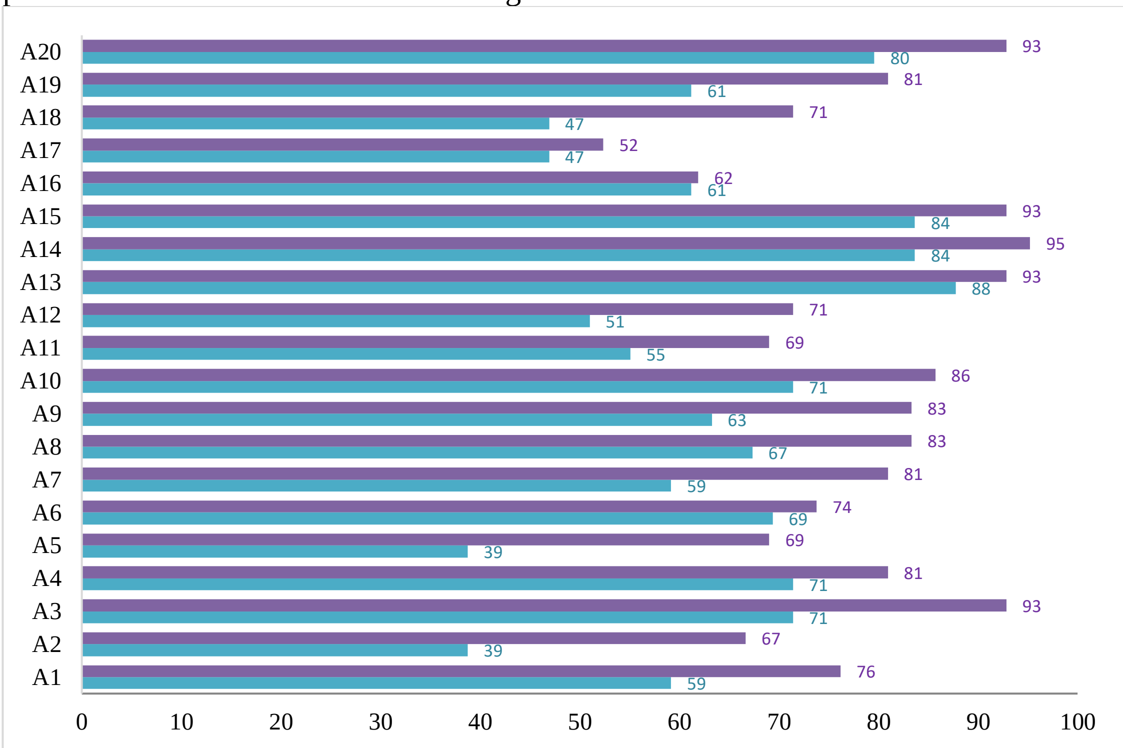


Figure 7. Student demographic and satisfaction score data

Based on the analysis of learning outcome satisfaction data obtained from student responses after learning, the application of SAM instructional design for project-based learning can significantly improve product design hard skills. Compared to students' visual demographic data before learning, the results show a better improvement. More detailed data on this can be seen in Table 6.

Table 6. Integration of demographics with student satisfaction

Level	Student demographics	Student satisfaction
Very High	1	6
High	3	6
Medium	5	6
Low	11	2

CONCLUSION

Based on the data presented, using SAM (Successive Approximation Model) instructional design for project-based learning can significantly improve students' AEEE product design hard skills. Evaluation of learning outcomes shows that students are delighted after being given learning materials. SAM instructional design can improve students' ability to analyze, think critically, and solve problems. Demographic data of students before and after learning shows a significant increase in student skills and satisfaction.

Thus, applying SAM instructional design to project-based learning can be an effective strategy for improving the quality of student learning and skills.

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