Jurnal Inovasi dan Teknologi Pembelajaran
Vol 10, No 3, (2023), page 234-247
https://doi.org/10.17977/um031v10i32023p234
P-ISSN: 2406-8780 E-ISSN: 2654-7953
Open access: http://journal2.um.ac.id/index.php/jinotep/index

The SAMR model for the development of learning device innovations in the subject of applying electronic circuits

Rykha Avadian Wahyudi, Ibut Priono Leksono, Ujang Rohman
Program Studi Teknologi Pendidikan Sekolah Pascasarjana Universitas PGRI Adi Buana Surabaya
Jl. Dukuh Menanggal XII/4 Surabaya, Jawa Timur, Indonesia
**Corresponding author, e-mail: rykhaavadianw@gmail.com*

ARTICLE INFO

Article history:
Received: 03-07-2023
Revised: 26-08-2023
Accepted: 04-09-2023

Kata kunci:
Perangkat pembelajaran; Model SAMR; Integrasi teknologi.

Keywords:
Learning tools; SAMR Models; Technology integration.

ABSTRAK

Tujuan penelitian ini untuk menghasilkan perangkat pembelajaran dengan model SAMR (substitution, augmentation, modification, redefinition) untuk mengintegasikan teknologi agar pembelajaran lebih inovatif dan kreatif serta meningkatkan pemahaman siswa. Prosedur pengembangan perangkat pembelajaran menggunakan metode pengembangan research and development (R&D) dan pendekatan model SAMR. Teknik pengumpulan data dilakukan dengan observasi dan angket. Tahap pengujian kelayakan dilakukan oleh ahli media, ahli desain, ahli materi, teman sejawat dan siswa. Hasil penilaian kelayakan ahli desain diperoleh prosentase 95,5 (valid). Ahli materi diperoleh prosentase 93,8 (valid). Ahli media diperoleh prosentase 83,8 (valid). Uji kepraktisan oleh teman sejawat diperoleh prosentase 91,7 (baik). Hasil respon terhadap produk di kelompok kecil diperoleh prosentase 98,9 (baik) dan uji coba kelompok besar diperoleh prosentase 97,5 (baik). Disimpulkan bahwa pengembangan perangkat pembelajaran penerapan rangkaian elektronika dengan model SAMR memudahkan siswa dan guru berkolaborasi mencapai tujuan pembelajaran dan mengembangkan kreatifitas dan inovasi siswa dengan mengintegrasikan teknologi serta dapat diterapkan dalam pembelajaran lainnya.

ABSTRACT

This research aimed to creates learning aids that use the SAMR (substitution, augmentation, modification, redefinition) model to integrate technology to make learning more original and creative while improving student's knowledge. The SAMR model approach and the Research and Development (R&D) method were used in the process of creating learning tools. Questionnaires and observation were used as data-collecting tools. Media specialists, design experts, material experts, coworkers, and students participated in the feasibility testing stage. A percentage of 95.5 (valid) was attained in the design expert feasibility evaluation results. Experts in material score 93.8 (valid). A valid percentage of 83.8 was given by media professionals. Colleagues' practicality test scored 91.7 out of 100, which is good. The results of the response to the product in the small group obtained a percentage of 98.9 (good), and in large group trials, it was 97.5 (good). It can be concluded that the development of learning tools applying electronic circuits using SAMR model makes it easier for students and teachers to collaborate in achieving learning goals and develops student creativity and innovation by integrating technology and can be applied in other learning.

INTRODUCTION

At present, every human being is required to solve a problem by thinking critically and to use information technology properly (Lestari et al., 2020). In the twenty-first century, investing in vocational education is a sort of education anticipated to improve the caliber of human resources. Vocational high school is a type of vocational education investment that, when put into practice, strives to satisfy the needs of the working world and give students the skills and knowledge they will need to live their lives in the future. A workforce with the skills and competencies required by the sector and the times is necessary for information technology, which is still developing (Wibowo & Munadi, 2020).

Students critical thinking skills are abilities that require attention in the classroom since they are crucial to their success in learning (Lu, 2022). Students' critical thinking skills are abilities that require attention in the classroom since they are crucial to their success in learning (Mahanal et al, 2019). Different methods have been created during the past ten years to use technology in classroom instruction. The most often used models are TPACK (Technological Pedagogical Content Knowledge), ACOT2 (Apple Classrooms of Tomorrow-Today), ATIM (Arizona Technology Integration Matrix), and SAMR (Substitution, Augmentation, Modification, Redefinition) (Crompton & Burke, 2020; Retana, 2021).

Today, information technology is widely used in both schools and colleges. Examples include the blending of computer technology, mobile devices, digital cameras, social media networks, software, the internet, and other technologies (Nyayu et al., 2019). Students can challenge conventional approaches in contemporary teaching and learning processes because to the integration of technology (Tang et al., 2020). Additionally, technology in education enhances both students' and teachers' learning capacities. Both teachers and students are urged to incorporate fresh approaches to make learning more interactive and dynamic (Binangbang, 2020).

Teachers must develop the ability to integrate technology to enrich student learning and assist in the accomplishment of educational goals (Caeiro-Rodríguez, 2018). It can be tough to choose the right digital tools, but teachers have a much harder time successfully incorporating technology into their classes. To foster student creativity, critical thinking, collaboration, and communication, teachers are needed to carry out learning activities that are in line with learning objectives through learning planning (Aldosemani, 2019). To handle the problems encountered by the students as well as improve academic achievements, teachers must be equipped with some effective technology integration strategies (Al-Khalidi & Nizwa, 2021).

At SMK Negeri 2 Kraksaan, one of the subjects in the 2013 curriculum is the application of electronic circuits. Industrial Electronics Engineering class XI students at SMK Negeri 2 Kraksaan learn this topic. They must be able to comprehend the teacher's explanation of electronic circuits and apply it to their practicum so that they may use it in daily life (Rohm, 2021). Students in TEI class XI who were interviewed said they had trouble understanding the teacher's explanations in electronics application studies. Additionally, they believed the practice was ineffective because not all students could utilize the equipment due to the school's low supply of tools. Class XI industrial electronics engineering teaches pupils the fundamentals of applying electronic circuits so they may better grasp other disciplines, increase their critical thinking abilities, and strengthen their sense of logic, creativity, and self-improvement (Cummings, 2022). Students still struggle with using their creative and technical knowledge of electronic circuits. Results of interviews and observations with the teaching staff regarding the use of electronic circuits provide proof of this. Students in class XI TEI engage in fieldwork activities during the even semester, which lasts for six months, from early January to June. So that students might learn online during that time rather than offline. Students have encountered a variety of challenges while learning offline, particularly while learning online, which is obviously challenging to understand and practice. In this case, the teacher must create a learning model that is appropriate and comfortable for PKL students to use so that their information may still be imparted, while still utilizing existing technology and being in compliance with the needs of students in each PKL location.

The choice of teaching strategies should produce the desired learning (Zhalalovna, 2020). Effective goals can be attained by using teaching styles that engage students and varied classroom management techniques (Miranda, 2020). In agreement with this, the findings of a related study

by Alfiana et al (2022) describe how many students struggle in their scholastic endeavors because they do not employ efficient study techniques.

SAMR (*Subtitution Augmentation Modification Redefinition*) model is a technique for examining how the use of technology may impact the process of teaching and learning, which illustrates the advancement of both educational technology and technological breakthroughs (Binangbang, 2020; Izza & Rusydiyah, 2020). An innovative approach to teaching and learning is the use of the SAMR model as a foundation for integrating technology to enhance student's capacity for creative thought. Four actions make up the SAMR model for integrating technology, namely: *Substitution,* Augmentation*, Modification, and Redefinition* (Aprinaldi, 2018). The SAMR Model can help institutions integrate their instructional procedures into four important areas that have arisen. It is a unit of knowledge, expertise, and e-learning in infrastructure, policy, and educational technology (Lubega & Paul, 2014). A four-level taxonomy-based method for choosing, utilizing, and assessing technology in K–12 educational contexts is called the Substitution, Augmentation, Modification, and Redefinition (SAMR) model (Hamilton, 2016). Mobile devices have the potential to revolutionize education as they take over more and more aspects of students' lives. Learning that is individualized, contextualized, and networked through the use of mobile devices is known as mobile-based learning or mLearning (Romrell, 2014).

Background issues connect to attempts to integrate technology, one approach to transforming technology into a blended learning environment. This is because it has become essential for educators who wish to participate in student-centered learning (Parrado-Martínez, 2020). One strategy to encourage students' creativity is for the teacher to provide teaching resources and offer material with a variety of models. Therefore, it is essential to conduct research and create educational tools using the SAMR model for SMK students who are studying applied electronic circuits.

METODE

Research on the SAMR (Substitution Augmentation Modification Redefinition) approach for the creation of learning tools for the use of electronic circuits. The SAMR model shows that using information and communication technologies while studying makes the idea of independent learning possible (Puentedura, 2021). Dr. Ruben Puentedura made the SAMR model famous by breaking it down into four stages and integrating it with the cognitive domain of Bloom's taxonomy to reach learning goals like Figure 1.

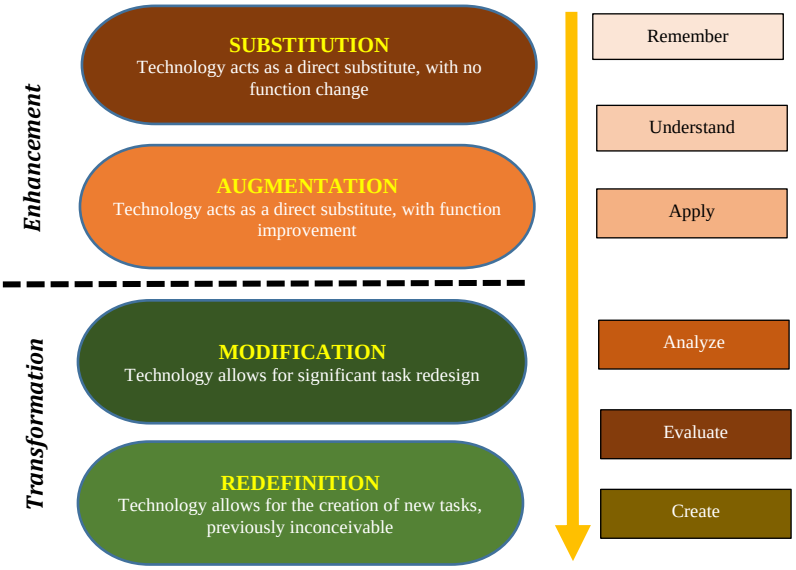


Figure 1. The relationship between the SAMR model and the levels of Bloom's Taxonomy

The first stage is the substitution (new) technology stage used for learning activities that are exactly the same as when the technology has not been adopted, which is marked by the stages of

replacing computer technology devices in preparing, compiling, and distributing materials, teaching materials, and evaluation sheets (Sanchez, 2021). Learning requires a level of thinking similar to memory and memorization.

The second stage is augmentation, in which learning activities comparable to those conducted before the adoption of the technology are used. However, technology is currently being applied to intensify these operations. It is defined by employing ICT for learning, assessment, and feedback in addition to simply substituting ICT gadgets (Yuwandra, 2020). Multiple applications, including cloud computing, Google Forms, and other technologies are already used at this stage. Skills and knowledge of concepts are the basic levels of thought needed for learning. A methodology called SAMR allows for the assessment of teachers' technological literacy. The matrix for creating learning activities with the SAMR model, which is described in Table 1.

The third stage, modification, involves using the new technology for learning tasks that have been sufficiently altered from the earlier iteration. It is characterized by changing the way that virtual courses interact by using interface tools like Google Classroom and comparable systems, where students have access to educational resources in the form of files, e-books, instructional videos, and other formats (Mazocco, 2021). Strategic thinking is the level of thinking needed for learning.

Table 1. The matrix for developing learning activities uses the SAMR model

Level	Scenarios of teaching and learning activities	Maturity-level argument
Substitution	• Students take attendance on the "ruang belajar" web. • Applications for video meetings are used by teachers to lecture students. • The teacher provides e-book references on the "ruang belajar" web. • The teacher assigns students to use manuscript processing software (Microsoft Word and PDF) to produce essays regarding product explanations that will be made and reports on product results.	• Students independently carry out independent attendance on the "ruang belajar" web and can immediately see the attendance recap. • Before adopting video meetings, the lecture technique was also tested. • Before using the e-book, the instructor distributed the book. • Teachers who want to use technology at this level need to be aware of the advantages of switching from traditional technology, such as flipcharts and chalkboards, to newer technology.
Augmentation	The teacher evaluates or gives assignments to students using the padlet application that has been shared through the teacher's website	In order to increase student motivation to continuously study independently and ask questions of the teacher, the teacher plans to test students using the online Padlet application, where students can immediately learn the results received. Teachers can also promptly and impartially assess the evaluation's results.
Modification	Discussion, brainstorming, and feedback The teacher assigns specific themes for investigation, discussion, or comment. Students list as many of their undeveloped concepts as they can.	In this case, anything is analyzed using Padlet. The teacher does not need to use numerous programs if the procedure of outlining undeveloped ideas and carefully reviewing them is carried out. Already, one Padlet application can promote diligent study. The outcomes of other groups' suggestions can be instantly discussed by teachers and other students.
Redefinition	Generating ideas for the framework of a larger work. Students are given a project to create by the teacher. A thorough brainstorming process is required.	Here, students create flip-pdf reports and product presentation movies, which are then published and posted to each student's YouTube channel for viewing by other audiences.

The fourth level, redefinition, involves using new technology for educational tasks that would not have been conceivable without it. It is defined by adjustments in learning activities that are more student-centered, where students can study freely, receive independently generated teaching materials, work on individually generated projects, and engage in autonomous conversations with the primary sources on assignments provided by the teacher (Silva, 2020). Strategic thinking (regarding teaching materials) and strategic thinking in the application of the teaching materials are the levels of thought necessary for learning.

The method was used to compare the percentage of survey responses with expert validation data and trials. The algorithm used to analyze information from media, materials, and learning design experts. Formula 1 is the treat the information as a whole (Sugiono, 2017) .

$$P = \frac{\Sigma x}{\Sigma xi}\ x\ 100\% \quad (1)$$

Formula Description: P= Percentage, Σx = The total score of the respondents' answers, and Σxi = Total maximum score of answers. After that, the outcomes of data management utilizing the aforementioned formula were compared with the validity in Table 2. In order to conduct research on the effectiveness of learning using the SAMR model, the findings of the learning evaluation questionnaire and student responses were analyzed. They were then grouped in accordance with Table 3.

Table 2. Product analysis criteria

Percentage	Qualification	Equivalent
75% - 100%	Valid	No revision needed
50% - 74.99%	Valid Enough	No revision needed
25% - 49.99%	Less Valid	Revision
0% - 24.99%	Invalid	Revision

Table 3. Rating Category Scale and Student Response

Precentage	Category
75% - 100%	Good
50% - 74.99%	Good enough
25% - 49.99%	Good less
0% - 24.99%	Not good

RESULTS

A learning implementation plan using the SAMR model is the end result. With the inclusion of additional capabilities to promote application excellence, the SAMR model will transform the learning system from what was initially traditional to information technology (Rini, 2022). The basic competency used in this development is to analyze the work of electronic circuit sensors with the SAMR model, which is described in teaching and learning activities, learning media using the study room website with the address http://rykha.smkn2kraksaan.sch.id/ to assist learning activities in moving in a better path in accordance with what is desired. The LMS in use in schools is supported by the website in Figure 2 so that teacher and student contact is made simple (Recke, 2021).

Among the learning exercises created using the SAMR syntax are:

1. Substitution
   a. Students take attendance on the ruang belajar web.
   b. The instructor repeats some of the previously presented theories while lecturing via the video meeting tool.
   c. Figure 3 illustrates how the instructor provides web links to e-books as a learning resource concerning sensors and transducers in the study session.
   d. Students are asked to use script processing software (Microsoft Word and PDF) to compose essays or create movies regarding the product explanations and results reports that will be made.

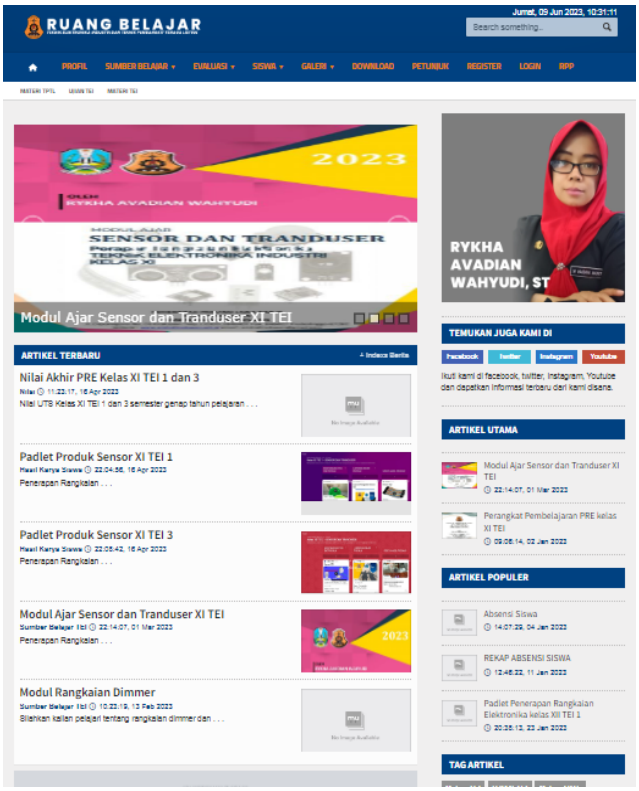


Figure 2. Ruang belajar website

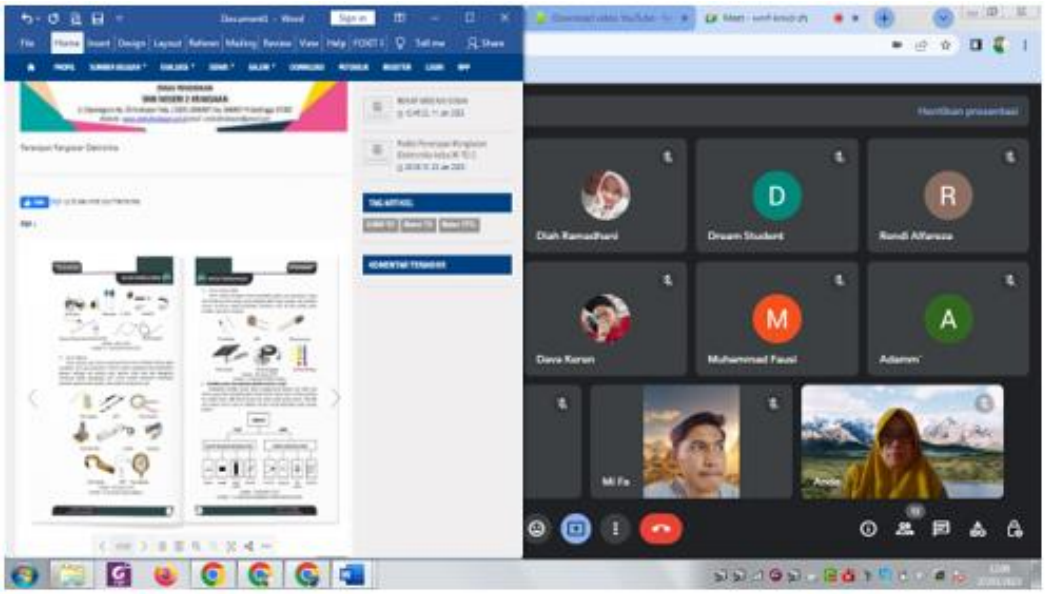


Figure 3. Stage of substitution

2. Augmentation

Using the Padlet application, which has been shared through the teacher's study room website, the teacher assigns homework to the pupils. As shown in Figure 4, students in their groups can post the outcomes of their assignments on the padlet where other groups and the teacher can view them. We can already see a functional improvement as a result of employing technology in the classroom.

3. Modification

Commentary from educators and other groups can be used for investigation and discussion. Students list as many of their undeveloped concepts as they can. At this point, students can also

use other technologies to assist with their tasks. For instance, they can simulate circuits created both online and offline using electronic programs like Tinkercad (see Figure 5).

4. Redefinition

At this point, the instructor gives the students the task of creating an episode in which they film themselves discussing and outlining the video or flip-chart report that they have created. Figure 6 illustrates how each student posts recordings of their product presentations to their YouTube channel so that other audiences can enjoy them.

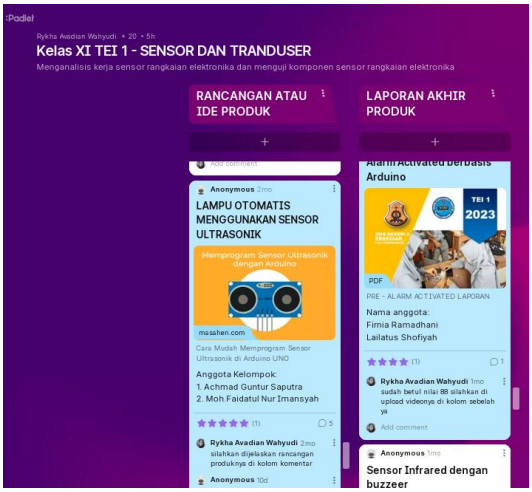


Figure 4. Stage of augmentation

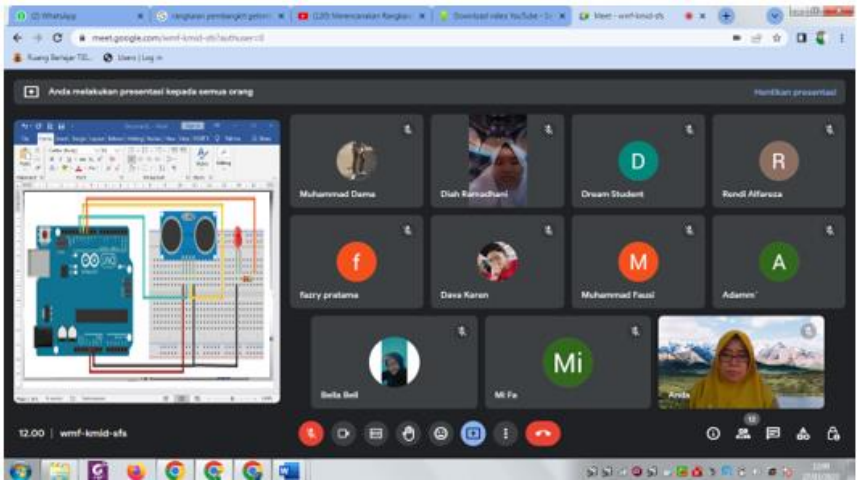


Figure 5. Stage of modification

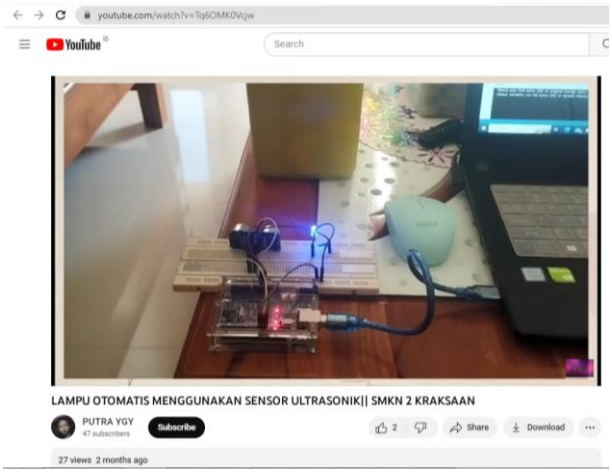


Figure 6. Stage of redefinition (link https://www.youtube.com/watch?v=Tq6OMK0Vcjw)

Design experts, media experts, material experts, and small- and large-group trials were used to validate the learning device. Students' attitudes and skills are evaluated to determine the efficacy of learning instruments in the implementation of learning. Analyzing data collected from students and coworkers to learn feedback and thoughts about the produced goods.

Design Expert Validation

A lecturer from UNIPA Adi Buana Surabaya's educational technology program conducted validation at this level. By evaluating many components of the formulation of learning objectives, content, and evaluation, design validation was carried out. The SAMR model learning device meets valid requirements, which indicates it is practicable and does not require revision to be used in learning, as shown in Table 4's overall findings of the validation data, which received a score of 42 with a percentage of 95.5%.

Table 4. The findings of experts in learning design validation

Aspect	Score Answer/ Score Max	P (%)	Qualification	Equivalent
Formulation of learning objectives	16/16	100	Valid	No revision needed
Content	19/20	95	Valid	No revision needed
Evaluation	7/8	87.5	Valid	No revision needed

Material Expert Validation

An effective instructor at SMK Negeri 2 Probolinggo with a major in industrial electronics engineering validated the information in this e-book. Aspects of the material's accuracy, breadth of coverage, depth, systematics, integrity, suitability, language, and image examples and illustrations were all validated. The validation from material experts is shown in the Table 5.

Table 5. Material expert validation results

Aspect	Score Answer/ Score Max	P (%)	Qualification	Equivalent
Material Accuracy	15/16	93.8	Valid	No revision needed
Breadth Coverage	3/4	75	Valid	No revision needed
Material Depth	4/4	100	Valid	No revision needed
Material Systematics	4/4	100	Valid	No revision needed
Material Integrity	7/8	87.5	Valid	No revision needed
Material suitability	15/16	93.8	Valid	No revision needed
Language	15/16	93.8	Valid	No revision needed
Example / Image Illustration	12/12	100	Valid	No revision needed

The overall results of the validation data obtained a score of 75 with a percentage of 93.8%, so based on the criteria it can be concluded that the learning material for applying electronic circuits with the SAMR model is in valid criteria which means it is feasible and does not need revision to be used in learning.

Media Expert Validation

An instructor in graduate education technology at PGRI Adi Buana University in Surabaya validated as the media experts. By giving an evaluation of the usability, functionality, and visual communication characteristics, the media was validated. Inferring from the data in Table 6 that the validation data overall obtained a score of 67 with a percentage of 83.8%, it can be said that the SAMR-based learning media satisfy valid criteria, meaning they are workable and don't require revision to be used in instruction.

Table 6. Media expert instrument grid

Aspect	Score Answer/ Score Max	P (%)	Qualification	Equivalent
Usability	21/24	87,5	Valid	No revision needed
Functionality	19/24	79,2	Valid	No revision needed
Visual Communication	27/32	84,3	Valid	No revision needed

Peer Response

Peer reviews conducted by one teacher who taught the same subject were used to get product testing, considering the implementationability, effectiveness, acceptability and attractiveness, sustainability, and environmental compatibility, as well as the reactions from colleagues.

Table 7 displays the outcomes of the peer answers. Based on the criteria, it can be said that the learning tool with the SAMR model fulfills good requirements for use in learning because it received a score of 33 and a percentage of 91.7%.

Table 7. The results of the response of colleagues

Aspect	Score Answer/ Score Max	P (%)	Category
Ability to be implemented	11/12	91.7	Good
Effectivenes	7/8	87.5	Good
Acceptance and attractiveness	4/4	100	Good
Continuity	4/4	100	Good
Compatibility with the environment	7/8	87.5	Good

Student Response

34 students were asked for their opinions, which were evaluated in terms of feasibility, viability, acceptability and attractiveness, and sustainability and environmental compatibility. Student responses were collected in Table 8 with a score of 1194 and a percentage of 97.5%.

Table 8. Results of student responses

Aspect	Score Answer/ Score Max	P (%)	Category
Ability to be implemented	397/408	97.3	Good
Effectivenes	267/272	98.2	Good
Acceptance and attractiveness	133/136	97.8	Good
Continuity	134/136	98.5	Good
Compatibility with the environment	263/272	96.7	Good

TESTS ON PRODUCTS

Trial in a small group

The average class grade in the small group trial, which involved 10 students in class XI TEI 1 at SMK Negeri 2 Kraksaan, was 78.6. The learning resources for PRE subjects with the SAMR model are classed as good for use in learning because they meet the minimal accomplishment level for class XI, which is 75. The outcomes of the small group trials are presented in Table 9.

Table 9. Results of the small group evaluation

No.	Category	Amount (Student)
1.	Good	4
2.	Good enough	6
3.	Good less	-
4.	Not good	-

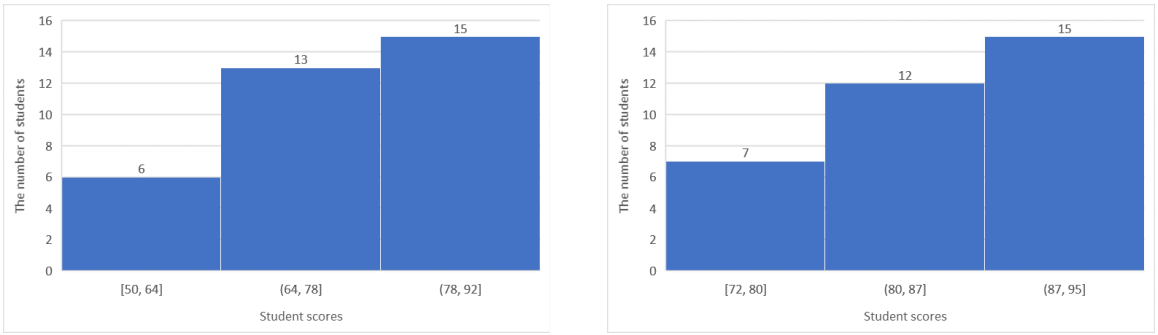
Large-scale trial

The average class score in the large group experiment, which involved 34 students in class XI TEI 3 at SMK Negeri 2 Kraksaan, which was 85. The learning tool for PRE subjects with the SAMR model is rated as good for use in learning, according to KKM class XI. The outcomes of the large group trials are presented in Table 10. As shown in the Figure 7, student learning outcomes prior to the teacher applying the SAMR paradigm, is shown below, compares to the outcomes of student learning when the instructor applies the SAMR paradigm (Figure 7). The SAMR model for learning can be inferred to fit good criteria for usage in learning based on the criteria. Students report feeling happier and more liberated to form opinions. In addition to being pleased and proud

when they can make items with a little assistance from the teacher. The SAMR methodology also increases students' enthusiasm for learning, which enables them to produce high-quality goods.

Table 10. Results of a large group evaluation

No.	Category	Amount (Student)
1.	Good	29
2.	Good enough	5
3.	Good less	-
4.	Not good	-



(a) (b)

Figure 7. Student learning outcomes before (a) and after (b) using the SAMR model

DISCUSSION

The teacher has solely utilized a dull teaching method up to this point, which consists of lectures, discussions, and handing the pupils uninteresting assignments. Students rapidly become bored as a result, and the lessons seem less intriguing (Sokip et al., 2022). The teacher can evaluate each student's attitudes and abilities while carrying out learning activities using the evaluation criteria listed in the learning process plan. Each teacher is required to create lesson plans that are thorough and methodical in order to ensure that learning happens collaboratively, in a way that is exciting, difficult, and inspiring and encourages students to take an active role, as well as by giving them opportunities to develop their interests, skills, creativity, and independence (Norra, 2018). One way to do this is by using a learning tool that educators utilize to carry out the teaching and learning process (Nair & Chuan, 2021). Learning issues for students, including the requirement for a variety of learning techniques in the teaching and learning process to boost student motivation and interest in studying and lessen boredom (Amorati, 2021).

The SAMR approach is a framework that teachers can use to decide what kind of technology to utilize and how to successfully incorporate it into the SAMR learning paradigm. Information on the SAMR model's application in educational activities is provided in Table 11. The SAMR model helps educators (teachers) by giving a summary of how learning is implemented in accordance with Bloom's Taxonomy, which is frequently used since it offers benefits (Drugova et al., 2021). In order to aid in the visualization of abstract concepts, technology integration into education can first make learning more creative and easily adapted to current technological developments (Yohandri, 2020). Currently particularly attentive students to technology advancements Teachers must be able to strike a balance between these traits. Teachers must be prepared to adapt and enhance learning activities by incorporating technology into them (Arantes, 2022). Second, there is intimate connection between the students and the material; this shows that students can be inspired to comprehend the information offered by the teacher so that they would actively participate in the learning process and develop their own knowledge.

Not only that, but by analyzing and taking something away from a learning process, students' skills can be grown and enhanced (Blundell et al., 2022). Thirdly, it can motivate educators to raise the bar for both teaching and learning by encouraging the creation of technology-assisted learning tools. According to the claim that the most successful learning aids are those that are prepared, tailored to the teacher's preferred learning model, and customized to the unique needs of each student (Chen, 2019).

Table 11. Implementing the SAMR paradigm to incorporate learning

Learning Activities	Time Allocation
Pre-learning activities Students divide into groups of two to three individuals each.	Before studying
Learning Activities	
• Talk about circuit designs or product concepts for sensor applications **(Substitution).**	1 hour
• Talk about the manufacturing process and challenges that were faced when producing the sensor application line of goods **(Augmentation).**	1 hour
• Between groups, share advice and criticism regarding the goods in the sensor application series **(Modification).**	1 hour
• Reports and videos about the outcomes of the sensor application series products should be created and posted to the appropriate YouTube channels and class pads **(Redefinition).**	1 hour
After learning activities The assessment is conducted in accordance with the designated assessment methodology. 1. Assessment of affect by watching attitudes while learning. 2. A psychomotor assessment using video demonstrations of the sensor application series' goods' outcomes	After studying

In addition to the aforementioned benefits, SAMR deployment has drawbacks as well. The SAMR model prioritizes the product over the process. Accordingly, learning the SAMR model can be compared to studying Bloom's taxonomy so that learning progresses via a number of concepts, starting with lower-order thinking skills and ending with higher-order thinking skills. This is consistent with analysis by Seibert (2021) because in order to build HOTS, it is crucial to create teaching tools employing the right learning models. Teachers should place less emphasis on what technology has to give and more emphasis on what is required for learning because the SAMR model is overly technocentric and measures the intensity and transformativeness of technology use in the classroom. If the instructor is still at a beginner's level, for instance, substitute teaching (Ilmi, 2020).

There seems to be considerable ambiguity at each level of the SAMR model. Each stage of this development is differentiated based on the teacher's expertise and viewpoint in integrating technology and adjusting to the needs of the pupils and the surroundings. In this instance, it is indisputable that digital technology aids students significantly (Kwangmuang, 2021). Students require abilities that can be utilized to prepare themselves for very fast-changing periods, particularly in information technology and global competition, according to the findings of expert validation and reactions to the development of learning aids utilizing the SAMR model (Amin, 2020). The world and technology are evolving constantly and quickly. ICT usage, however, should only be done to improve learning's efficacy and efficiency (Autapao, 2018). This development is carried out context-sensitively, i.e., by adding context as a formal aspect in the framework of thinking so that learning objectives can be achieved through creative and innovative learning, as opposed to the SAMR model which ignores context, an important aspect in research and practice related to educational technology (Niswatin & Zainiyati, 2020)

CONCLUSION

Students' needs to gain first-hand experience with the production of sensor application circuit products using the SAMR model and learning resources in the form of a study room website can be met by the development of learning the SAMR model in the subject of applying electronic circuits for class XI majoring in industrial electronics engineering at vocational schools. This allows communication between teachers and students to be intertwined even without having to do virtual learning. The aforementioned findings have satisfied the research and development goals, which were to create learning device products in the form of lesson plans using the SAMR model, identify learning barriers for students, identify student responses in subjects involving

electronic circuits using the SAMR model, and identify student learning outcomes using the SAMR model. Although prior research indicated that the SAMR model had some shortcomings, these flaws could be fixed by collaborating on Bloom's taxonomy in learning activities, incorporating several modern technologies, and always implementing student-centered learning to make students feel happier and more liberated in formulating ideas. The SAMR methodology also increases students' enthusiasm for learning, which enables them to produce high-quality goods. Although the development of SAMR model learning tools is still restricted to class XI SMK, it may be applied as a model for use in the learning process in other productive subjects by modifying the facilities and infrastructure at school as well as the technology integration skills of each instructor.

Author contributions

The authors made significant contributions to the study's conception and design. The authors was in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

Funding

There was no specific grant for this research from any funding organization in the public, private, or nonprofit sectors.

Conflict of interest

The authors declare that there is no potential conflict of interest.

Data availability statement

All data are available from the authors.

REFERENCES

Al-Khalidi, I., & Nizwa, O. (2021). Examining Teachers' Beliefs on Developing a Digital Pedagogical Framework Based on the SAMR Model for Undergraduate English Language Learning. In *International Journal of English Language Education*. pdfs.semanticscholar.org. https://doi.org/10.5296/ijele.v9i1.18306

Aldosemani, T. (2019). Inservice Teachers' Perceptions of a Professional Development Plan Based on SAMR Model: A Case Study. *TOJET: The Turkish Online Journal of Educational Technology*, *18(3)*, 46–53. https://eric.ed.gov/?id=EJ1223786

Alfiana, H., Karyono, H., & Gunawan, W. (2022). The Application Of Samr Model And Self-Efficacy On Critical Thingking And Procedural Knowledge. *LLT Journal: A Journal on Language and Language Teaching*, *25(1)*, 200–217. https://doi.org/10.24071/llt.v25i1.3893

Amin, A. M. (2020). The correlation between metacognitive skills and critical thinking skills at the implementation of four different learning strategies in animal physiology lectures. *European Journal of Educational Research*, *9*(1), 143–163. https://doi.org/10.12973/eu-jer.9.1.143

Amorati, R. (2021). Fostering motivation and creativity through self-publishing as project-based learning in the Italian L2 classroom. *Foreign Language Annals*, *54*(4), 1003–1026. https://doi.org/10.1111/flan.12568

Aprinaldi, A. (2018). Integrating SAMR learning model in vocational education. In *IOP Conference Series: Materials Science and Engineering* (Vol. 434, Issue 1). https://doi.org/10.1088/1757-899X/434/1/012309

Arantes, J. (2022). The SAMR model as a framework for scaffolding online chat: a theoretical discussion of the SAMR model as a research method during these "interesting" times. *Qualitative Research Journal*. https://doi.org/10.1108/QRJ-08-2021-0088

Autapao, K. (2018). Effects of basic character design and animation concepts using the flipped learning and project-based learning approach on learning achievement and creative thinking of higher education students. In *AIP Conference Proceedings* (Vol. 1923). https://doi.org/10.1063/1.5019494

Binangbang, J. (2020). The Effect of Substitution, Augmentation, Modification and Redefinition Model on Students' Writing Skills. *Middle Eastern Journal of Research in Education and Social Sciences*, *1(2)*, 29–51. https://doi.org/10.47631/mejress.v1i2.131

Blundell, C. N., Mukherjee, M., & Nykvist, S. (2022). A scoping review of the application of the SAMR model in research. In *Computers and Education Open* (p. 100093). Elsevier.

https://doi.org/10.1016/j.caeo.2022.100093
Caeiro-Rodríguez, M. (2018). Creation-based learning and artistic education: Projects classroom between metacognition and metaemotion. *Arte, Individuo y Sociedad*, *30*(1), 159–177. https://doi.org/10.5209/ARIS.57043
Chen, S. (2019). Effect of project-based learning on development of students' creative thinking. *International Journal of Electrical Engineering Education*. https://doi.org/10.1177/0020720919846808
Crompton, H., & Burke, D. (2020). Mobile learning and pedagogical opportunities: A configurative systematic review of PreK-12 research using the SAMR framework. *Computers & Education*, 156. https://doi.org/10.1016/j.compedu.2020.103945
Cummings, C. (2022). Design thinking and community impact: A case study of project-based learning in an MBA capstone course. *Journal of Education for Business*, *97*(2), 126–132. https://doi.org/10.1080/08832323.2021.1887795
Drugova, E., Zhuravleva, I., Aiusheeva, M., & Grits, D. (2021). Toward a model of learning innovation integration: TPACK-SAMR based analysis of the introduction of a digital learning environment in three Russian universities. In *Education and Information Technologies* (pp. 4925–4942). Springer. https://doi.org/10.1007/s10639-021-10514-2
Hamilton, E. R. (2016). The Substitution Augmentation Modification Redefinition (SAMR) Model: a Critical Review and Suggestions for its Use. *TechTrends*, *60*(5), 433–441. https://doi.org/10.1007/s11528-016-0091-y
Ilmi, A. (2020). Development of TPACK based-physics learning media to improve HOTS and scientific attitude. In *Journal of Physics: Conference Series* (Vol. 1440, Issue 1). https://doi.org/10.1088/1742-6596/1440/1/012049
Izza, A., & Rusydiyah, E. F. (2020). Analisis model SAM/R pada guru Pendidikan Agama Islam dalam mengembangkan motivasi belajar siswa. *Edureligia: Pendidikan Agama Islam*, *04(01)*, 11–34. https://doi.org/10.33650/edureligia.v4i1.1107
Kwangmuang, P. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon*, *7*(6). https://doi.org/10.1016/j.heliyon.2021.e07309
Lestari, D., Haryani, S., & Sumarti, S. S. (2020). Analysis of critical thinking skills in vocational high school automotive engineering students. *Journal of Advances in Education and Philosophy*, *4(6)*, 234–237. https://doi.org/10.36348/jaep.2020.v04i06.002
Lu, S. Y. (2022). Evaluation of Disabled STEAM-Students' Education Learning Outcomes and Creativity under the UN Sustainable Development Goal: Project-Based Learning Oriented STEAM Curriculum with Micro:bit. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020679
Lubega, J. T., & Paul, M. (2014). *Adoption of the SAMR model to asses ICT pedagogical adoption: A case of Makerere University*. pub.nkumbauniversity.ac.ug. https://doi.org/10.7763/ijeeee.2014.v4.312
Mahanal, S; Zubaidah, S; Sumiati, I; et al. (2019). RICOSRE: A Learning Model to Develop Critical Thinking Skills for Students with Different Academic Abilities. *International Journal of Instruction*, *12(2)*, 417–434. https://doi.org/10.29333/iji.2019.12227a
Mazocco, L. A. R. (2021). The development of an Educational Tool for the Teaching of Distributed Generation and Renewable Energy Concepts in Elementary Schools. In *2021 Brazilian Power Electronics Conference, COBEP 2021*. https://doi.org/10.1109/COBEP53665.2021.9684116
Miranda, M. (2020). Active, experiential and reflective training in civil engineering: evaluation of a project-based learning proposal. *European Journal of Engineering Education*, *45*(6), 937–956. https://doi.org/10.1080/03043797.2020.1785400
Nair, R. S., & Chuan, T. C. (2021). Integrating technology that uses modified SAMR model as a pedagogical framework in evaluating learning performance of undergraduates. *The Educational Review, USA*, *5*(10), 373-384. https://doi.org/10.26855/er.2021.10.001
Niswatin, K., & Zainiyati, H. S. (2020). Implementasi Model SAMR (Substitution, Augmentation, Modification, Redefinition) di MI Al Ishlah Glagah Lamongan. *TADRIS: Jurnal Pendidikan Islam*, *15(2)*, 283–293. https://doi.org/10.19105/tjpi.v15i2.3512
Norra, B. I. (2018). Pengembangan Perangkat Pembelajaran Kontekstual dengan Pendekatan Guided Inquiry Materi Tumbuhan Berbiji Pada Siswa SMK Farmasi Nusaputera. *Al-Hayat: Journal of Biology and Applied Biology*, *1(1)*, 27. https://doi.org/10.21580/ah.v1i1.2684
Nyayu, S. Y., Heru, S., & Masagus, S. (2019). The Use of Technology Integration SAMR Model in Teaching English. *IDEAS: Journal on English Language Teaching and Learning, Linguistics and Literature*, *7(1)*. https://doi.org/10.24256/ideas.v7i1.720
Parrado-Martínez, P. (2020). Development of competences in postgraduate studies of finance: A project-

based learning (PBL) case study. *International Review of Economics Education*, *35*. https://doi.org/10.1016/j.iree.2020.100192

Puentedura, R. (2021). *Ruben R. Puentedura's Weblog: SAMR: Moving from enhancement to transformation. Hippasus*.

Recke, M. P. (2021). Emergent narratives in remote learning experiences for project based education. *Electronic Journal of E-Learning*, *19*(2), 59–70. https://doi.org/10.34190/ejel.19.2.2142

Retana, R. C. (2021). Technology Integration Models into adult education: TPACK and SAMR. In *Actualidades Investigativas en Educacion* (pp. 1–27). scielo.sa.cr. https://doi.org/10.15517/aie.v21i1.42411

Rini, T. A. (2022). Development of E-module Teaching Simulation Tools in SIPEJAR for Teaching Practice of Prospective Teacher Students. In *Proceedings - 2022 2nd International Conference on Information Technology and Education, ICIT and E 2022* (pp. 122–126). https://doi.org/10.1109/ICITE54466.2022.9759551

Rohm, A. J. (2021). Future Proof and Real-World Ready: The Role of Live Project-Based Learning in Students' Skill Development. *Journal of Marketing Education*, *43*(2), 204–215. https://doi.org/10.1177/02734753211001409

Romrell, D. (2014). The SAMR model as a framework for evaluating mLearning. *Journal of Asynchronous Learning Network*, *18*(2). https://doi.org/10.24059/olj.v18i2.435

Sanchez, R. E. P. (2021). Development of online teaching tools for engineering: immersive virtual reality application for manipulation of a vertical milling machine using unity. In *Future of Educational Innovation Workshop Series - Machine Learning-Driven Digital Technologies for Educational Innovation Workshop 2021*. https://doi.org/10.1109/IEEECONF53024.2021.9733774

Seibert, S. A. (2021). Problem-based learning: A strategy to foster generation Z's critical thinking and perseverance. *Teaching and Learning in Nursing*, *16*(1), 85–88. https://doi.org/10.1016/j.teln.2020.09.002

Silva, J. B. (2020). Technological structure for technology integration in the classroom, inspired by the maker culture. *Journal of Information Technology Education: Research*, *19*, 167–204. https://doi.org/10.28945/4532

Sokip, S., Sumbawati, M. S., & Sitompul, N. (2022). Implementasi aplikasi mind mapping sebagai perangkat pembelajaran era revolusi industri 5.0. *JIPI (Jurnal Ilmiah Penelitian Dan Pembelajaran Informatika)*, *07*, 487–495. https://doi.org/10.29100/jipi.v7i2.2844

Sugiono. (2017). Metode Penelitian Pendidikan (pendekatan kuwantitatif, kuwalitatif, R&D). In *Alfabbeta Pres*.

Tang, T., Vezzani, V., & Eriksson, V. (2020). *Developing critical thinking, collective creativity skills and problem solving through playful design jams. Thinking Skills and Creativity, 37, 100696* (p. 37). https://doi.org/10.1016/j.tsc.2020.100696

Wibowo, M. A. A., & Munadi, S. (2020). Critical Thinking Skills through Industrial Revolution 4.0 for Vocational Education. *VANOS Journal Of Mechanical Engineering Education*, *91(2)*. https://doi.org/10.30870/vanos.v5i2.8784

Yohandri. (2020). Development of student worksheets (SW) based on project based learning models assisted by tracker applications with scientific approach on simple harmonic motion. *International Journal of Scientific and Technology Research*, *9*(2), 1434–1437. https://doi.org/10.1088/1742-6596/1481/1/012126

Yuwandra, R. (2020). Development of learning tools based on contextual teaching and learning in fifth grade of primary schools. In *Journal of Physics: Conference Series* (Vol. 1554, Issue 1). https://doi.org/10.1088/1742-6596/1554/1/012077

Zhalalovna, K. L. (2020). Development of students' individual creativity in higher education institutions: Project based learning. *Universidad y Sociedad*, *12*(2), 380–384. https://api.elsevier.com/content/abstract/scopus_id/85100905628