# The Expert Validation of Virtual Reality-Based Learning Media of Flexible Manufacturing Systems (FMS)

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ABSTRACT

The advancement of digital technology has had a significant impact on the world of education, including vocational education that requires in-depth technical understanding. In this study, Virtual Reality (VR)-based learning media is an alternative to help the process of introducing engineering components more interactively and realistically. This study aims to validate VR-based learning media called Virtual Reality Distributing Station as a learning media in learning distribution station components in the Flexible Manufacturing System (FMS). Validation is carried out through evaluation by experts with a focus on two main aspects, namely, the content aspect and the media display aspect. Material experts are experts who are experienced in teaching FMS, while media experts come from experts in the development of computer-based learning media. Data analysis is carried out based on quantitative and qualitative results obtained from expert validation. The evaluation results show that the content aspect of the material, which includes suitability and usefulness, scored 87 out of 96 (90.27%) and is categorized as "very good." Meanwhile, the media aspect, which includes display design and usefulness, scored 61.5 out of 72 (85%) and is also categorized as "very good". These findings indicate that the VR Distributing Station learning media is suitable for use as a supporting tool for engineering learning in vocational education.



## 1. Introduction

The advancement of technology has significantly influenced various fields, particularly education. Technology in education does not only aim to digitize content but also focuses on creating entirely new learning experiences, transforming learning environments to be more inclusive and accessible by accommodating students' diverse needs [1]. Integrating digital technology into learning has enhanced students' effectiveness, efficiency, and motivation. It has also facilitated the understanding of complex materials through more transparent and interactive visualizations [2]. Modern educational technologies, including e-learning, interactive media, Augmented Reality and Virtual Reality (VR), have enabled a more personalized, engaging, and effective learning approach [3], [4]. Among these innovations, immersive technologies such as Virtual Reality (VR) have emerged as one of the most promising developments, offering the unique potential to revolutionize many aspects of educational practice [5].

Virtual Reality (VR) has great potential in education, creating immersive, interactive, and often personalized learning experiences that exceed traditional teaching methods [6]. The technology enables students to directly experience abstract concepts or complex scenarios instead of merely reading or hearing about them. This approach has enhanced student engagement, fostered deeper conceptual understanding, and improved long-term knowledge retention. [7]. The increased student engagement provided by virtual reality (VR) is not an end goal but rather an important factor that leads to improved cognitive outcomes. VR's immersive nature helps reduce external distractions and enhance focus, while its interactive features allow for self-directed exploration and discovery. Together, these elements create ideal conditions for deeper processing of information [5]. VR facilitates the acquisition of practical skills by providing a simulated environment where students can practice and apply their knowledge in a realistic yet safe context [6]. The relevance and learning media of VR have become increasingly apparent in vocational education, where the development of practical skills is at the heart of the learning process.

Virtual Reality (VR) stands out in vocational education for its unique advantage in providing a platform for practical skills training. VR allows students to simulate complex and high-risk tasks in a safe and controlled virtual environment without any adverse physical or financial consequences in the real world [8][9]. The main advantage is the provision of safe failure environments, which allow students to make mistakes, learn from them, and practice repeatedly, which is crucial for mastering technical skills. VR learning media in vocational education are diverse, including training for industrial machine operations, welding procedures, automotive repair, and medical simulations [10]. The use of VR aims to teach both theoretical and procedural aspects, which significantly improves competence and critical thinking [5], [11], [12], [13]. VR can be used broadly in terms of practical work in vocational education, such as Flexible Manufacturing Systems.

Flexible Manufacturing System (FMS) is an automated and integrated production system that offers high flexibility in product variety, volume, and production efficiency, with three main components: workstations, automated material handling systems, and central computers [14]. Distribution stations are crucial elements in ensuring the smooth flow of materials between workstations, as well as in theoretical and practical FMS learning. However, the spatial complexity and dynamic interactions between FMS components, especially at distribution stations, are often difficult to understand through conventional learning media such as textbooks, 2D diagrams, or physical models. These media are currently unable to present interactive and realistic visualizations in a three-dimensional environment, thereby limiting students' understanding of the system's workflow and reducing their readiness to face the real manufacturing environment.

Research has been conducted that emphasizes the use of Virtual Reality as an interactive learning medium in engineering education [15], [16]. However, validation by experts regarding the substance of the material or media design has not been carried out, and its learning media has not been directed in the context of FMS. The FMS simulator has been developed as an Arduino-based learning medium for technical institutions [17]. However, system testing has not included the validation process by experts (expert judgment), both in terms of manufacturing materials and learning media. This study also integrated Virtual Reality technology into the development of the Virtual Flexible Manufacturing (VFM) system; there has been no validation by experts to assess the feasibility of the content or the effectiveness of the media [18]. Based on the analysis of the development of existing learning media, a problem or gap exists in that the learning media developed have not been validated against expert judgment.

To overcome these problems, this study developed learning media that focused on evaluating learning media for introducing distribution stations in the Flexible Manufacturing System (FMS) based on Virtual Reality (VR). This media is designed so that students can interact directly in a three-dimensional virtual environment that resembles real conditions. This condition is in line with the trend in educational technology research, especially in virtual reality, which focuses on developing new tools and critically evaluating their feasibility and pedagogical effectiveness in specific learning contexts [19]. This study fills the gap in previous studies that rarely evaluate the use of VR specifically for FMS learning. The novelty of this study lies in the integration of FMS content into VR and expert validation from two sides—learning media and FMS materials—to ensure technical, pedagogical, and content suitability in the context of vocational education [20], [21].

This study aims to validate the Virtual Reality-based learning media that has been developed in order to ensure the technical, pedagogical, and content suitability in supporting the FMS learning process. Validation was carried out by two groups of experts to obtain a comprehensive evaluation of the effectiveness of the media in the context of vocational education. The main contribution of this study is to present an alternative interactive learning media while strengthening the scientific basis for media development with a systematic evaluation approach. Thus, this study is expected to be a reference in the development of other VR learning media that are relevant to the fields of engineering and vocational education.

## 2. Method

In this study, a Virtual Reality (VR)--based Distributing Station learning media was developed as a learning medium in vocational education. This learning media is designed to project a virtual environment of the distribution station in three dimensions (3D) so that it can replace the role of physical media in the process of introducing and learning components in the Flexible Manufacturing System (FMS), especially the distributing station section. This learning media is the object of expert-based evaluation to assess its feasibility as a substitute for direct practice in a physical laboratory.

This learning media was developed using various supporting software. Blender is used to create 3D models of each component of the distribution station. These components are depicted in detail and realistically to support the user's spatial understanding. Unity 3D software version 2020 acts as a game engine that integrates 3D components with the user interface and interaction flow in the learning media. Programming is done using the C# language through Microsoft Visual Studio 2017, while Adobe Photoshop is used to design visual elements and learning media interface layouts. To support compatibility on Android devices, the learning media is also developed using the Android SDK with the Java programming language.

Figure 1 shows a screenshot of the user interface of the Virtual Reality-based Distribution Station learning media. The media interface display provides several main menus, namely Instructions, Info, Objectives, Materials, and the Exit button. The Materials menu is a core feature that presents a comprehensive introduction to each distributing station component in the form of 3D visualization that users can explore. The components displayed and explained in the Materials menu include vacuum switches, cable clips, plates, connectors, air service units, fiber optics, station link receivers, PLCs, CP valves, Terminal I/O, Changer Modules and Stack Modules, one-way flow, rotary actuators, proximity sensors, suction cups, acting cylinders, and micro switches. At the top of each component's interface, users can select and navigate to view the names, functions, and installation illustrations of components in the FMS system.


**Fig. 1.** The user interface of the Virtual Reality-based Distribution Station learning media

This visualization not only provides a visual representation of the physical form but also illustrates the interconnectedness between components within the operational context of the distribution station. Thus, this learning media enables students to understand the function and role of each component in greater depth without relying on physical laboratory facilities. Overall, the VR Distributing Station learning media supports practical learning by providing an interactive, realistic, and safe experience that allows users to become familiar with the key components of a distribution station within a Flexible Manufacturing System environment.

## 3. Method

This study aims to validate the Virtual Reality (VR) as a learning medium for the Distributing Station. Validation is carried out to ensure that the development of this technology-based learning media meets the criteria of the material and media aspects. Four experts conducted the validation process: two material experts and two media experts, all of whom have backgrounds in manufacturing systems and engineering education, with more than five years of work experience. Assessment based on the content aspect includes the structure and completeness of the content on the topic of distribution stations, as well as its suitability with learning outcomes in vocational education programs. Meanwhile, the assessment of the media aspect refers to the appearance of the user interface in the context of computer-based multimedia, including color composition, text display, 3D image quality, sound quality, and interface navigation.

The assessment process begins with the preparation of an assessment instrument intended for material experts and computer-based learning media experts. The instrument grid is compiled based on theoretical studies related to the distribution structure in FMS, as well as the principles of the quality of VR technology-based learning media. Each item in the instrument is developed based on the indicators in the grid to form an assessment questionnaire using a 4-point Likert scale. The instrument that has been developed is then validated by an educational evaluation expert concerning the indicators and principles of developing the right instrument to assess the feasibility of this VR learning media.

### 3.1. Development of Expert Validation Instruments

The instrument used to evaluate the Virtual Reality (VR) Distributing Station learning media is a 4-point Likert scale questionnaire. This evaluation aims to obtain quantitative and qualitative data. Quantitative data is used to determine the level of feasibility of VR-based learning media, while qualitative data consists of suggestions, input, and comments from experts on the developed learning media. The feasibility criteria for technology-based learning media refer to the principles and indicators established in several previous studies, as stated by [22], [23], [24], [25]. Based on this study, the feasibility of this VR learning media is assessed from two main aspects: validation of material content and media.

The material content evaluation instrument consists of two aspects, namely, the material suitability aspect and the usefulness aspect. The aspect of material suitability encompasses seven indicators: suitability with basic competencies, suitability with the needs of student learners, grammar, correctness of the material, clarity, flexibility and depth of the material, and sequence of the material. For the aspect of the material's usefulness, there are three indicators: attracting students' attention to the leaf, facilitating students' understanding, and the suitability of images with writing. The structure and grid of the material expert instrument are shown in Table 1.

**Table 1.** The material expert's instrument grids and indicators

| *Aspect* | *Indicators* | *Number* |
|---|---|---|
| Material suitability | Suitability with Basic Competencies | 1,2 |
| | Suitability with the needs of student learners | 3,4,5 |
| | Grammar | 6,7 |
| | Correctness of the material | 8,9 |
| | Clarity | 10,11 |
| | Flexibility and depth of the material | 12,13,14 |
| | Sequence of the material | 15,16 |

| *Aspect* | *Indicators* | *Number* |
|---|---|---|
| The usefulness | Attracts students' attention to learning | 17,18 |
| | Facilitates students' understanding | 19,20,21,22 |
| | Suitability of images with writing | 23,24 |

The media content validation instrument consists of two aspects, namely display design and media usefulness. The display design aspect has four indicators: layout, accuracy of writing and components, attractiveness, and ease. While the media usefulness aspect also has four indicators, namely facilitating learning, attracting students' attention, increasing motivation, and helping students' understanding. Table 2 shows the media expert instrument grid.

**Table 2.** The media expert's instrument grids and indicators

| *Aspect* | *Indicators* | *Number* |
|---|---|---|
| Display design | Layout | 1,2 |
| | Accuracy of writing and components | 3,4,5,6 |
| | Attractiveness | 7,8 |
| | Ease | 9,10 |
| Media usefulness | Facilitates learning | 11,12 |
| | Attracts students' attention | 13,14 |
| | Increases motivation | 15,16 |
| | It helps students understand | 17,18 |

### 3.2. The Instrument's Validity

An instrument is declared valid if it can be used to measure what it is intended to measure. This validity test aims to determine the accuracy of the instrument as a measuring tool. There are two stages in the instrument validity test, namely construct validity and content validity. Construct validity is assessed based on the composition of the instrument. The instrument has strong construct validity if its items are related to the aspects discussed. Content validity is ensured by verifying that the instrument's contents align with the topic being measured. Construct validity testing is conducted by consulting experts in their respective fields. While the content validity test is based on statistical calculations, this study uses the Product Moment formula to test its validity [26].

### 3.3. The Process of Validation

The instrument was declared valid based on the assessment by the validation expert, allowing it to proceed to the next stage, namely evaluating the learning media product. The evaluation was conducted using two types of instruments: evaluation instruments for content experts and instruments for learning media experts. The content experts consisted of two experts from the Electrical Engineering Vocational Education program who taught the Flexible Manufacturing System (FMS) course. The learning media experts consisted of two experts specializing in computer-based learning technology. The selection of FMS experts as material experts was based on the suitability of their fields of expertise, ensuring the objectivity of the assessment and the input provided was truly relevant, given their teaching experience. Meanwhile, the selection of media experts was carried out based on their background of expertise in computer-based learning technology to ensure objectivity in the interface and multimedia aspects.

Before the evaluation was conducted, the experts received a brief demonstration of the VR Distributing Station learning media. The demonstration explained the learning media's features, navigation, and procedures for use, supporting an understanding of the components and functions of the distribution station. Furthermore, the experts were allowed to try the system independently and explore its available features. Discussion and question-and-answer sessions were also held to clarify parts that had not been explained in detail. After that, the evaluation questionnaire was distributed according to the assessment aspects to obtain quantitative data, which was then analyzed to determine the level of learning media feasibility. In addition, qualitative data in the form of comments and suggestions from experts were also collected as input for improving the media.

### 3.4. Criteria for Eligibility

The data obtained from the results of expert judgment (media experts and material experts) are in the form of quantitative data with a 4-point Likert scale. The quantitative data is analyzed to determine the level of feasibility of the developed learning media. The determination of the percentage of feasibility is based on the total value obtained from each expert and the total maximum value, as shown in Equation (1). The feasibility level category is arranged based on Table 3 [27].

$$\text{Eligibility Percentage} = \frac{\text{Obtained value}}{\text{Maximum value}}\, x\, 100\% \quad (1)$$

**Table 3.** Eligibility category percentage

| *Value in percent* | *Category* |
|---|---|
| 81 – 100 % | Very Good/Very Worthy |
| 61 – 80 % | Good/Worthy |
| 41 – 60 % | Quite Good/Quite Worthy |
| 21 – 40 % | Not Good/Unworthy |
| <21 % | Very Bad/Very Worthy |

## 4. Results and Discussion

This section presents the research results, analysis, and discussion based on the validation by experts. The evaluation of the feasibility of this virtual reality learning media was carried out by experts in learning materials, as well as media experts.

### 4.1. Learning Materials Validation

The feasibility of developing media materials to introduce distributing station components assisted by Virtual Reality in the flexible manufacturing system practice course is determined by material experts. This validation requires two experts as a benchmark for feasibility. Providing a questionnaire is used as a technique to assess the feasibility of the media that has been created. The results of the questionnaire, which was filled out by the validator, are in the form of scores on a scale of 1-4, with a total of 24 statement items. The statements are divided into two aspects: the aspect of material suitability, comprising 15 items, and the element of material usefulness, comprising nine items. The material validation data from the experts are shown in Table 4.

**Table 4.** The material validation data from the experts

| *Aspect* | *Item number* | *Min Score* | *Max Score* | *Validator 1* | *Validator 2* |
|---|---|---|---|---|---|
| Material suitability | 1 | 1 | 4 | 4 | 4 |
| | 2 | 1 | 4 | 3 | 4 |
| | 3 | 1 | 4 | 3 | 4 |
| | 4 | 1 | 4 | 4 | 4 |
| | 5 | 1 | 4 | 3 | 4 |
| | 6 | 1 | 4 | 3 | 4 |
| | 7 | 1 | 4 | 3 | 4 |
| | 8 | 1 | 4 | 4 | 4 |
| | 9 | 1 | 4 | 3 | 4 |
| | 10 | 1 | 4 | 3 | 4 |
| | 11 | 1 | 4 | 3 | 4 |
| | 12 | 1 | 4 | 4 | 4 |
| | 13 | 1 | 4 | 3 | 4 |
| | 14 | 1 | 4 | 3 | 4 |

| *Aspect* | *Item number* | *Min Score* | *Max Score* | *Validator 1* | *Validator 2* |
|---|---|---|---|---|---|
| | 15 | 1 | 4 | 4 | 4 |
| The usefulness | 16 | 1 | 4 | 4 | 4 |
| | 17 | 1 | 4 | 4 | 4 |
| | 18 | 1 | 4 | 4 | 4 |
| | 19 | 1 | 4 | 4 | 3 |
| | 20 | 1 | 4 | 3 | 3 |
| | 21 | 1 | 4 | 4 | 4 |
| | 22 | 1 | 4 | 4 | 4 |
| | 23 | 1 | 4 | 3 | 3 |
| | 24 | 1 | 4 | 3 | 3 |
| Total | | 24 | 96 | 83 | 92 |

The data obtained from each statement item, based on each material expert, is accumulated with a maximum limit of 96 scores and a minimum of 24 scores. The results in Table 4 were then analyzed to determine the percentage of suitable media. The following material validation results are summarized in Table 5.

**Table 5.** Analysis of material validation data

| *Aspect* | *Skor Max* | *Score Validator 1* | *%* | *Score Validator 2* | *%* | *Total Average* | *% Total* | *Category* |
|---|---|---|---|---|---|---|---|---|
| Material suitability | 60 | 50 | 83.33 | 60 | 100 | 55 | 91.67 | Very Good |
| The usefulness | 36 | 32 | 88.89 | 32 | 88.89 | 32 | 88.89 | Very Good |
| Total | 96 | 82 | | 92 | | 87 | 90.27 | Very Good |

Based on Tables 4 and 5, virtual reality media obtained a very good category from two validators. The aspect of material suitability reached 91.67% and usefulness 88.89%. These results indicate that the material aligns with the targeted learning needs and competencies. The validators gave high scores on the suitability of the content to the objectives, clarity of information, and integration of context. The usefulness of the media was also considered high because it was able to improve conceptual understanding and support independent exploration. VR media is considered effective if the content is authentic, contextual, and applicable [28]. This finding suggests that the development of similar media should prioritize the integration of content quality and user experience, focusing on the principles of content integration and ease of access. This approach can ensure that the media is not only visually appealing but also has high instructional value, thereby increasing the overall effectiveness of learning.

### 4.2. Media Aspect Validation

The quality and working system of the development of Virtual Reality-assisted distributing station component introduction media in the flexible manufacturing system practice course can be seen from the assessment of validation experts. Providing a questionnaire is used as a technique to determine the feasibility of the media that has been created. The results of the questionnaire, which was filled out by the validator, are in the form of a score with a scale range of 1-4, comprising a total of 18 statement items. The statements are divided into two aspects: the appearance design aspect, comprising 10 items, and the material usefulness aspect, containing eight items. The media validation data from the experts are shown in Table 6.

**Table 6.** The media validation data from the experts

| *Aspect* | *Item number* | *Min Score* | *Max Score* | *Validator 1* | *Validator 2* |
|---|---|---|---|---|---|
| Display design | 1 | 1 | 4 | 4 | 3 |
| | 2 | 1 | 4 | 3 | 3 |
| | 3 | 1 | 4 | 4 | 4 |
| | 4 | 1 | 4 | 3 | 3 |
| | 5 | 1 | 4 | 4 | 3 |
| | 6 | 1 | 4 | 3 | 3 |
| | 7 | 1 | 4 | 4 | 4 |
| | 8 | 1 | 4 | 4 | 4 |
| | 9 | 1 | 4 | 4 | 4 |
| | 10 | 1 | 4 | 3 | 4 |
| Media usefulness | 11 | 1 | 4 | 4 | 3 |
| | 12 | 1 | 4 | 2 | 2 |
| | 13 | 1 | 4 | 4 | 3 |
| | 14 | 1 | 4 | 4 | 3 |
| | 15 | 1 | 4 | 3 | 4 |
| | 16 | 1 | 4 | 3 | 3 |
| | 17 | 1 | 4 | 4 | 3 |
| | 18 | 1 | 4 | 4 | 3 |
| Total | | 18 | 72 | 64 | 59 |

The data obtained from each item of the media expert review statement are accumulated to a maximum of 72 scores and a minimum of 18 scores. The results in Table 6 were then analyzed to determine the percentage of suitable media. The following media validation results are summarized in Table 7.

**Table 7.** Analysis of media validation data

| *Aspect* | *Skor Max* | *Score Validator 1* | *%* | *Score Validator 2* | *%* | *Total Average* | *% Total* | *Category* |
|---|---|---|---|---|---|---|---|---|
| Display design | 40 | 36 | 90% | 35 | 87,5% | 35,5 | 88,75 | Very Good |
| Media usefulness | 32 | 28 | 87,5% | 24 | 75% | 26 | 81,25 | Very Good |
| Total | 72 | 64 | | 59 | | 61.5 | 85 | Very Good |

Based on Tables 6 and 7, the developed VR media received a very good category from two validators. The display design aspect scored 88.75% and the usability aspect 81.25%. These results indicate that the main advantages lie in the visual design and interactivity of the media, which are considered effective in supporting engineering learning. This finding aligns with the previous research [29], which highlights that visual realism and immersive experiences in VR environments can enhance engagement and understanding of abstract concepts in the STEM concept. However, the lowest score appeared on one of the usability indicators (item 12), which indicates the need for evaluation of certain features The implications of this assessment provide important input for the development of similar VR media, namely by emphasizing the principle of user-centered design. Therefore, the media developed is not only visually attractive but also functional, applicable, and supports the optimal achievement of learning competencies [28].

### 4.3. The Product Revision

The product revision stage is carried out based on the results of qualitative data analysis obtained from experts. This qualitative data consists of suggestions, input, and comments provided by material experts and media experts on the Virtual Reality (VR) Distributing Station learning media that has been developed. This input serves as a valuable reference for enhancing specific aspects of the learning media, including both content and visual presentation, as well as functionality. Table 8 shows qualitative data from expert suggestions.

**Table 8.** Comments and suggestions from experts

| ***Value in percent*** | ***Category*** |
|---|---|
| Material Experts | Background replaced by introduction. |
| | Benefits do not need to be included in the module. |
| | Bullets are replaced by letters or numbers. |
| | In the image section, which is still part of one description, alphabet separators are used. |
| | The purpose of the task section is explained more clearly. |
| | Improve the sentence pattern of questions in the evaluation. |
| | The multiple-choice section in the evaluation is arranged dynamically, making it difficult for students to guess the answers easily. |
| Media Experts | It would be better if it were developed not only the introduction of components but also their use and operation of the distributing station system. |
| | Can be conveyed with additional specifications for each component |
| | Writing the material section containing components, if possible, is made more apparent, and the title is not material but distributing station components |

Based on comments from experts, it was found that the learning media for the virtual reality-based distribution station was feasible in terms of media and still needed improvement in terms of material. Suggestions from material experts were more towards improvements to the module book for the VR-based Distribution Station learning media. Experts suggested a more comprehensive writing and explanation system. Based on all comments and suggestions from material experts and media experts in Table 8, several improvements were made to improve the quality of the media developed.

The title "Background" was changed to "Introduction" by changing the term "Background" at the beginning of the media to "Introduction." This aims to make the presentation of initial information feel more communicative and direct to the context of media use, in accordance with the characteristics of interactive learning modules that are concise and focused. The section containing an explanation of the benefits of learning media has also been removed according to expert advice. All sections of the list that previously used bullet symbols have been changed to use a numbering or alphabetical system, as shown in Figure 2(a). This change was made to clarify the sequence, strengthen the logical structure in conveying information, and make it easier for students to understand the contents of each point systematically. In the section that displays several elements in one image or illustration, adjustments have also been made by labelling them with alphabetical letters (such as a, b, c, and so on), as shown in Figure 2(b).

(a)

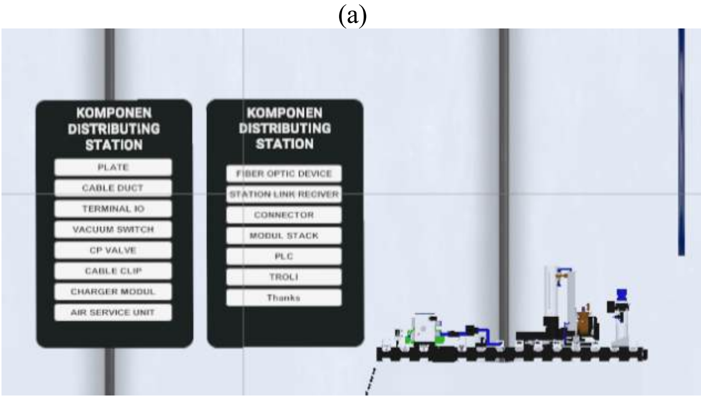
(b)

**Fig. 2.** (a) Revision on numbering, and (b) Layout of image section

The previously unclear task section has been improved by providing a more explicit explanation regarding the intent of each instruction. The description includes the purpose of the task, the steps to complete it, and the form of the final result that must be submitted by students so that there is no confusion in its implementation. Sentences in the evaluation section, especially questions, have been improved to be more straightforward, unambiguous, and correct language rules. This improvement is expected to improve understanding of questions and minimize the possibility of multiple interpretations from students. To prevent students from guessing the answers from repeated option patterns, the answer choices in the evaluation questions have been rearranged randomly (dynamically). This step was taken so that students are encouraged to understand the material truly, not just rely on memorizing answer patterns. The section title previously called "Material" has been changed to "Distributing Station Components" to adjust to the content of the discussion. In addition, the writing of the components in this section has also been clarified with a more organized structure, more informative descriptions, and supporting illustrations to aid understanding.

As a follow-up to suggestions from media experts, revisions have been made to the media section, especially those related to the appearance and content of the learning media. Several important components, such as the vacuum switch, air service unit, proximity sensor, and suction cup, are now accompanied by detailed technical explanations to be more informative, as shown in Figure 3(a). This addition aims to ensure that students not only recognize the shape and name of the components visually through VR media but also understand the technical characteristics that are relevant to practices in the industrial world. After that, the title of the material section was changed, which was initially called "Material" to "Distributing Station Components" to be more representative of the content and focus of learning. In addition to changing the title, this section was also rearranged with a more systematic and informative structure, including explanations of functions and 3D visualizations, as shown in Figure 3(b). This revision is expected to enrich students' learning experience with an approach that is not only visually interactive but also technically educational and applicable.


(a)




(b)

**Fig. 3.** Revision of (a) additional explanations for each component, and (b) change of title and layout

## 5. Conclusion

The development of digital technology has brought significant changes in the world of education, including vocational education, which requires a deep understanding of engineering products. In this context, technology-based learning media such as Virtual Reality (VR) are an effective alternative solution for visually and interactively introducing engineering components. This study develops and evaluates the Virtual Reality (VR) distributed learning media as a virtual laboratory for introducing distribution station components in the Flexible Manufacturing System (FMS). Validation is carried out based on expert evaluations, which are divided into two main aspects, namely the content aspect and the media content aspect. Content experts are selected from experienced professionals who specialize in teaching FMS, while media experts are drawn from those with expertise in developing computer-based learning media. Data analysis is based on quantitative and qualitative data generated from validation with experts. The results of the analysis show that the level of learning media feasibility from the content aspect of the material, which includes the suitability and usefulness of the material, obtained a total score of 87 out of 96 or 90.27%.In comparison, the media aspect, which includes display design and media usability, obtained a total score of 61.5 out of 72, or 85%, both of which fall into the "very good" category. These findings suggest that visual representation and interactive interface design are the most prominent elements in supporting learners' understanding. At the same time, some features require improvement in terms of both functionality and alignment with learning outcomes. Thus, the effectiveness of VR media development in the context of engineering education is not only determined by the sophistication of technology but also by the integration of content quality, visual design, and expertise-based validation processes that can ensure that the media is truly adaptive to vocational learning needs.

## References

[1] C. del R. Navas-Bonilla, J. A. Guerra-Arango, D. A. Oviedo-Guado, and D. E. Murillo-Noriega, “Inclusive education through technology: a systematic review of types, tools and characteristics,” *Front Educ (Lausanne)*, vol. Volume 10-2025, 2025, doi: 10.3389/feduc.2025.1527851.

[2] M. Drolia, S. Papadakis, E. Sifaki, and M. Kalogiannakis, “Mobile Learning Applications for Refugees: A Systematic Literature Review,” *Educ Sci (Basel)*, vol. 12, no. 2, 2022, doi: 10.3390/educsci12020096.

[3] M. Imran, N. Almusharraf, S. Ahmed, and M. I. Mansoor, “Personalization of E-Learning: Future Trends, Opportunities, and Challenges.,” *International Journal of Interactive Mobile Technologies*, vol. 18, no. 10, 2024.

[4] H. Tolle, T. Miningrum, and F. A. Bachtiar, “The Effectiveness of Augmented Reality with Adapted Books as Emotional Expression Media for Children with Autistic Spectrum Disorders (ASD),” 2024.

[5] R. Vats Shivani and Joshi, “The Impact of Virtual Reality in Education: A Comprehensive Research Study,” in *Transfer, Diffusion and Adoption of Next-Generation Digital Technologies*, Y. K. and M. B. and L. B. and E. A. Sharma Sujeet K. and Dwivedi, Ed., Cham: Springer Nature Switzerland, 2024, pp. 126–136.

[6] X. He and W. Hoe Tan, “Analysis of the Teaching Effectiveness of Virtual Reality Technology in Higher Education,” *Salud, Ciencia y Tecnología - Serie de Conferencias*, vol. 4, p. 1274, Jan. 2025, doi: 10.56294/sctconf20251274.

[7] G. Lampropoulos, “Combining Artificial Intelligence with Augmented Reality and Virtual Reality in Education: Current Trends and Future Perspectives,” *Multimodal Technologies and Interaction*, vol. 9, no. 2, 2025, doi: 10.3390/mti9020011.

[8] V. McIntosh, “Dialing up the danger: Virtual reality for the simulation of risk,” *Front Virtual Real*, vol. Volume 3-2022, 2022, doi: 10.3389/frvir.2022.909984.

[9] M. Yazdi, “Augmented Reality (AR) and Virtual Reality (VR) in Maintenance Training,” in *Advances in Computational Mathematics for Industrial System Reliability and*

*Maintainability*, Cham: Springer Nature Switzerland, 2024, pp. 169–183. doi: 10.1007/978-3-031-53514-7_10.

[10] Z. Ziyang and N. Mohamad Nasri, “Immersive Virtual Reality in Vocational School: A Systematic Literature Review,” *International Journal of Academic Research in Progressive Education and Development*, vol. 14, no. 1, Feb. 2025, doi: 10.6007/IJARPED/v14-i1/24694.

[11] M. M. Asad, A. Naz, P. Churi, and M. M. Tahanzadeh, “Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review,” *Educ Res Int*, vol. 2021, no. 1, p. 7061623, 2021, doi: https://doi.org/10.1155/2021/7061623.

[12] K. Liu, W. Zhang, W. Li, T. Wang, and Y. Zheng, “Effectiveness of virtual reality in nursing education: a systematic review and meta-analysis,” *BMC Med Educ*, vol. 23, no. 1, p. 710, 2023, doi: 10.1186/s12909-023-04662-x.

[13] A. Marougkas, C. Troussas, A. Krouska, and C. Sgouropoulou, “Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade,” Jul. 01, 2023, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/electronics12132832.

[14] G. Manu, V. Kumar M, H. Nagesh, D. Jagadeesh, and M. B. Gowtham, “Flexible Manufacturing Systems (FMS), A Review,” *International Journal of Mechanical and Production Engineering Research and Development*, vol. 8, pp. 323–336, May 2018, doi: 10.24247/ijmperdapr201836.

[15] A. K. Ghazali, N. A. Nor, K. Ab. Aziz, and N. Tse Kian, “The usage of virtual reality in engineering education,” *Cogent Education*, vol. 11, no. 1, 2024, doi: 10.1080/2331186X.2024.2319441.

[16] S. Shen, “Application and Implementation Methods of VR Technology in Higher Education Mechanical Manufacturing Programs,” in *Proceedings - 2023 International Conference on Educational Knowledge and Informatization, EKI 2023*, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 48–51. doi: 10.1109/EKI61071.2023.00018.

[17] V. N. Kalbande *et al.*, “A Research Paper on Flexible Manufacturing System Simulator for Technical Institutes,” *International Journal of Innovative Science and Research Technology (IJISRT)*, pp. 1845–1854, Jun. 2024, doi: 10.38124/ijisrt/ijisrt24may1652.

[18] Z. Sun, “A Flexible Manufacturing System based on Virtual Simulation Technology for Building Flexible Platforms,” 2023. [Online]. Available: www.ijacsa.thesai.org

[19] H. Sung, M. Kim, J. Park, N. Shin, and Y. Han, “Effectiveness of Virtual Reality in Healthcare Education: Systematic Review and Meta-Analysis,” *Sustainability*, vol. 16, no. 19, 2024, doi: 10.3390/su16198520.

[20] N. Melethadathil, B. Nair, S. Diwakar, and J. Heringa, “Mining inter-relationships in online scientific articles and its visualization: Natural language processing for systems biology modeling,” *International journal of online and biomedical engineering*, vol. 15, no. 2, pp. 39–59, 2019, doi: 10.3991/ijoe.v15i02.9432.

[21] D. Hariyanto and T. Köhler, “A web-based adaptive e-learning application for engineering students: An expert-based evaluation,” *International Journal of Engineering Pedagogy*, vol. 10, no. 2, pp. 60–71, 2020, doi: 10.3991/ijep.v10i2.11834.

[22] A. Rahmadi, I. Hanafi, and S. Sukardjo, "Development of Virtual Reality-Based Learning Media for Product-Setting Subjects in Vocational Schools," *Journal of World Science*, vol. 2, no. 9, pp. 1330–1339, Sep. 2023, doi: 10.58344/jws.v2i9.419.

[23] A. Febriana, R. Joharmawan, R. Hakiki, and M. Muchson, "Development of virtual reality-based learning media on chemical bond materials and molecular shapes for grade 10th of senior high school students," in *Improving Assessment and Evaluation Strategies on Online Learning*, Routledge, 2022, pp. 108–114. doi: 10.1201/9781003261346-17.

[24] R. Djouab and M. Bari, "An ISO 9126 Based Quality Model for the e-Learning Systems," *International Journal of Information and Education Technology*, vol. 6, no. 5, pp. 370–375, 2016, doi: 10.7763/IJIET.2016.V6.716.

[25] S. Mishra and R. C. Sharma, *Interactive Multimedia in Education and Training*. United State: Idea Group Publishing, 2005. [Online]. Available: https://www.researchgate.net/publication/27377999

[26] R. Hidayati, A. S. Kusmanto, and A. Kiswantoro, "Development and Construct Validation of Indonesian Students Self-Confidance Scale Using Pearson Product Moment," *Pegem Journal of Education and Instruction*, vol. 13, no. 3, Jan. 2023, doi: 10.47750/pegegog.13.03.11.

[27] S. Arikunto, *Dasar-Dasar Evaluasi Pendidikan Edisi 2*. PT Bumi Aksara, 2016.

[28] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," *Comput Educ*, vol. 147, Apr. 2020, doi: 10.1016/j.compedu.2019.103778.

[29] G. Makransky and L. Lilleholt, "A structural equation modeling investigation of the emotional value of immersive virtual reality in education," *Educational Technology Research and Development*, vol. 66, no. 5, pp. 1141–1164, Oct. 2018, doi: 10.1007/s11423-018-9581-2.