Journal of Information Systems Engineering and Management
2025, 10(1s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Development of STEM Integrated Project Based Learning Model in Vocational Education

Akmal[1], Ambiyar[2], Usmeldi[3]

[1,2,3]*Faculty Teknik, Universitas Negeri Padang, Padang, Indonesia.*

[1]*akmalaurel01@gmail.com,* [2]*ambiyar@ft.unp.ac.id,* [3]*usmeldy@yahoo.co.id*

ARTICLE INFO

Received: 02 Oct 2024

Revised: 29 Nov 2024

Accepted: 10 Dec 2024

ABSTRACT

The purpose of this research is to develop a Project-Based Learning model integrated with STEM and to measure its validity and practicality levels. This research uses the development model from Borg & Gall, by reducing the development stages into four phases: 1) Data collection phase, 2) Planning and design phase, 3) Development phase, 4) Validation and trial phase. The sample involves experts for the evaluation, as well as students from class XI of the Light Vehicle Engineering Power Transmission System subject, and also includes teachers. The data collection tool used is a questionnaire, and the data analysis technique is conducted descriptively. The findings show that the product produced consists of a model book, teaching module, teacher guide, and student guide. This model produces 7 steps, which include: 1) Providing the problem to be faced, 2) Giving students freedom, 3) Planning and developing the project, 4) Organizing the schedule and monitoring the project, 5) Evaluating the project, 6) Communication and reflection, 7) sentence incomplete, please provide the next part for translation. Providing rewards to students within the group. The developed learning model has also been proven to be valid and practical, making it usable. The suggestion from this finding is that it is expected to be applied to other subjects, and there is a need to stimulate and motivate students in implementing this learning model, so that the learning process can be focused, effective, and efficient.

Keywords: STEM, Project Based Learning, Vocational Education.

INTRODUCTION

The development of the 4.0 revolution is marked by the increasing connectivity of interactions as well as the advancement of digital systems, artificial intelligence, and data-driven digital intelligence, promoting critical thinking, creativity, communication, and collaboration. Preparing human resources requires foundational scientific competencies that are developed through the design of science, technology, engineering, and mathematics (STEM), supporting the development of technological knowledge in the Internet of Things (IoT) based on data.

The business and industrial sectors accept graduates of Vocational High Schools who are skilled in accordance with the interests and talents they pursue. According to Law No. 20 on the National Education System, vocational education is secondary education that prepares students to work in specific fields.

Graduates of Vocational High Schools prepare their expertise competencies in accordance with the needs of the workforce (Nuryanto, & Eryandi, 2020); (Hidayatuloh, & Muslim, 2021); (Kamaludin, et, al, 2022). These graduates equip themselves with multidisciplinary knowledge that meets the demands of the times, possessing high skills based on the Pancasila profile, creativity, independence, cooperation, discipline, mutual assistance, and innovation. Schools are required to foster both academic abilities and skills for living together. Success in education can be influenced by several factors, including the application of learning models based on the characteristics of learning (Made et al., 2022). One of these is vocational education, which emphasizes the mastery of knowledge, skills, attitudes, and values needed in the industrial world. To meet the demands of technological innovation in education, it is necessary to use innovative 21st-century learning models. One such project-based learning model

produces marketable products while simultaneously preparing students to enter the business and industrial world. Vocational High Schools (SMK) are oriented toward producing a workforce for the labor market. Therefore, professional teachers are needed to apply methods and strategies according to the competencies they possess. SMK graduates are expected to be able to compete in the workforce with the competencies they have. Students must be able to create products.

Based on documentation studies and interviews with teachers of the productive subject for Class XI Light Vehicle Engineering Power Transmission System at SMK Negeri 1 Pariaman, this subject is a key productive course in light vehicle engineering. Currently, the school implements the Merdeka Curriculum using conventional teaching methods. Students have difficulty analyzing, and their literacy and numeracy skills are still low, especially in the fields of science, technology, engineering, and mathematics (STEM), making it hard for them to understand the fundamentals of vocational theory. In 21st-century learning, the teacher has not yet developed students' attitudes/soft skills during the learning process.

Another issue during the delivery of learning material is that the teacher directly gives written or practical tasks to students without assessing how well the students have understood the material that has been presented. As a result, many students still do not fully grasp the taught content. Students are not given meaningful responsibilities to complete tasks. Additionally, there is a lack of innovative learning media for the light vehicle engineering concentration, and the learning process does not align with real-world scenarios. Students have not yet developed critical thinking skills, and many students' scores are below the minimum completion criteria. Student learning outcomes are also still lacking. Observations also revealed that students are not able to work collaboratively in teams; they tend to rely on the abilities of one peer. The lack of attention from students during material delivery is likely due to the inappropriate and non-innovative learning model used, which is suspected to be the cause of these issues.

The weaknesses of the applied learning model can also be seen through the teacher-centered learning process, which leads to many issues during the lessons. Therefore, it is necessary to prepare students who are disciplined, critical thinkers, creative, collaborative, and responsible for completing meaningful tasks. A shift in the learning approach is required, from *teacher-centered* to *student-centered*. With these efforts, it is hoped that the quality of learning and student learning outcomes can be improved. The efforts to optimize and refine the learning process of the Light Vehicle Engineering Power Transmission System subject will focus on the development of a *Project-Based Learning* model integrated with *Science*, *Technology*, *Engineering*, and *Mathematics* (STEM).

The development of *Project-Based Learning*, which is the selection of the right learning model, plays an important role in shaping students' character, knowledge, and skills. This model is carefully prepared from the beginning of the learning process to the selection of the appropriate learning model in 21st-century education. The *Project-Based Learning* model provides a real solution through training and skills. Project-based learning gathers new knowledge and applies interpersonal skills in real-life experiences, which is effective in encouraging students to reflect and think critically for life and work (Fajra *et al.,* 2020).

Project-Based Learning is a learning model that emphasizes complex learning. In this model, students take on the central role, replacing the teacher in problem-solving and completing the assigned projects (Karnando et al., 2021). *Project-Based* Learning is a learning model that organizes lessons around projects (Made et al., 2018). The development of *project-based learning* refines teaching materials according to the needs and characteristics of the students (Muslim et al., 2020).

The weakness of the *Project-Based Learning* model in addressing this issue is the effort to improve the learning process of the Light Vehicle Engineering Power Transmission System subject, by enhancing the quality of the selected learning material, which must have project-based characteristics. The learning practices are relatively long and student-centered, integrated with the real world, creating permanent knowledge and organizing projects in the learning process. This also holds great potential to create engaging and meaningful learning experiences for students to enter the workforce (Indrawan et al., 2019)**.**

One of the solutions implemented is able to support and enhance the competencies of graduates by applying the project-based learning model. *Project-based learning* is at the forefront of instilling 21st-century skills, preparing students to become productive members of the global community, proactive and adaptive learners who direct themselves toward performance improvement, and solving complex engineering problems that resemble real-world

scenarios. Project-based learning is a teaching model that produces a product as an output (Siti Khoiruli et.al., 2019).

The *Project-Based Learning* model applied by teachers in the learning process helps students gain a better understanding of the material and is able to increase student engagement, as well as improve the learning outcomes achieved by the students (Made et al., 2022). *Project-based learning* emphasizes education that provides opportunities for a student-centered learning system. The *project-based learning* model applied by teachers in the learning process helps students master the material more effectively and is capable of increasing student engagement and improving the learning outcomes achieved by the students (Made et al., 2022). One of them is STEM, which can create a meaningful learning context (Siti Khoiruli, et al., 2019). STEM can improve problem-solving skills, be creative (Permanasari, 2016); (Mulyani, 2019); (Ridha, et al, 2022). STEM in its implementation can be applied in vocational schools, because it can support students' skills (Wannapiroon, et al, 2021); (Nurtanto, etl al, 2020); (Akgunduz, Mesutoglu, 2021); (Chondrogiannis, et al, 2021); (Nurtanto, et al, 2020); (Ayuso, et al, 2022).

Based on the issues that have been outlined, there is a need for educational innovation in the 21st century by developing a learning model. This research aims to develop a *Project-Based Learning* model integrated with STEM and measure its validity and practicality.

METHOD

This research uses the development model from Borg & Gall, by reducing the development stages into four stages (Emzir, 2013), namely: 1) Data Collection Stage, which involves preliminary studies and needs analysis. 2) Planning and Design Stage, which includes designing the syntax of the developed model and its products. 3) Development Stage, where the model and products are created, followed by testing in a focus group discussion. 4) Validation and Testing Stage, where model and product validation, practicality testing, and effectiveness testing of the developed model are conducted.

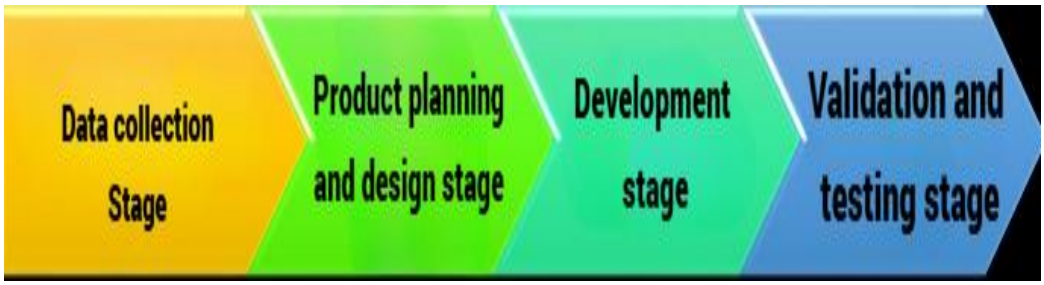

Figure 1: Tahapan pengembangan

The sample involves experts for validation, totaling 5 individuals with expertise in various fields, including a language expert, a learning model expert, a teaching media expert, and a subject matter expert. It also involves students from grade XI, enrolled in the Light Vehicle Engineering Power Transmission System subject during the July-December 2024 semester, as well as teachers. Data collection tools include questionnaires and learning outcome tests. The data analysis technique is conducted descriptively.

RESULT AND DISCUSSION

Education can be improved through the use of a good curriculum that is adapted to the development of technology. This aligns with the growth of education, producing graduates who are skilled and professional, meeting the needs of the industry. Educational institutions must be capable of preparing human resources with the foundational scientific competencies that are developed through the design of science and technology education.

The issues that occur during the delivery of learning material include ineffective teaching, the unavailability of innovative learning media, the lack of the use of learning models, low student learning outcomes, a lack of product-based learning, and a tendency for teacher-centered learning.

The need for the development of *Project-Based Learning*, which is the selection of the right learning model, plays a crucial role in shaping students' character, knowledge, and skills. This model is carefully prepared from the

beginning of the learning process to the selection of the appropriate learning model for 21st-century education. The *Project-Based Learning* model provides a real solution through training and skill development. Project-based learning gathers new knowledge and allows students to practice interpersonal skills in real-life experiences, which is effective in helping students reflect and think critically for life and work (Fajra *et al.,* 2020). Therefore, a combination of educational innovations in the 21st century is needed by developing the *Project-Based Learning* model integrated with STEM. The STEM model can create a meaningful learning context (Siti Khoiruli, et al., 2019).

The development of this learning model adopts the Research and Development (R&D) research method, adapted from Borg and Gall into four stages, namely: 1) Data Collection Stage, which includes preliminary studies and needs analysis. 2) Planning and Design Stage, which involves designing the syntax of the developed model and its products. 3) Development Stage, where the model and product are created, followed by testing in a focus group discussion. 4) Validation and Trial Stage, where model and product validation, practicality testing, and effectiveness testing of the developed model are conducted.

Stage 1: Data Collection Stage

In this stage, the researcher conducts a preliminary study to review references for the model to be developed. A needs analysis is carried out, and the results show that both students and teachers require the development of the model. Learning materials, syllabi, and supporting materials for creating the product are collected, including the model book, teaching modules, teacher guides, and student guides. This collection of resources will form the foundation for developing and implementing the learning model.

Stage 2: Planning and Design Stage

In the planning and design stage, the design and development of models are carried out, such as designing model books, guidebooks, and teaching modules. The design of the Project-Based Learning model integrated with STEM for the subject of Light Vehicle Engineering Power Transmission Systems includes: syntax, social systems, reaction principles, supporting systems, and instructional and accompanying impacts. It also includes research instruments.

Table 1: Syntax of Learning Model Development PjBL-STEM

Learning Syntax Project Based Learning based STEM
Providing the problems that will be faced
Providing freedom to students
Plan and develop *projects*
Prepare schedules and monitor *projects*
Assessing *projects*
Communication and reflection
Give *rewards* to students in groups

The model book is designed and developed based on literature sources, relevant theories, and model concepts related to *Project-Based Learning* integrated with STEM. This model book contains explanations of the developed model, concepts, syntax, and learning steps for both teachers and students. Below is the display of the model book.

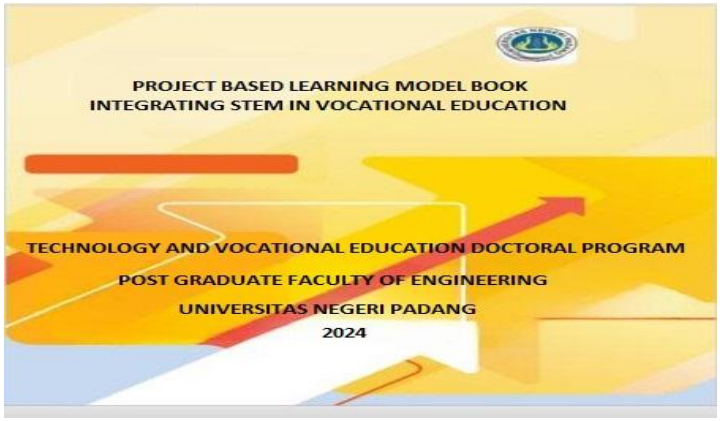

Figure 2: Model Book Cover

The teacher's guidebook contains learning activities for teachers. It includes instructional guidelines, a guide for project-based learning model activities, conducting learning evaluations, teacher practice activity sheets, and others. The steps in the teacher's guide are outlined. Below is the design and plan of the teacher's guide:

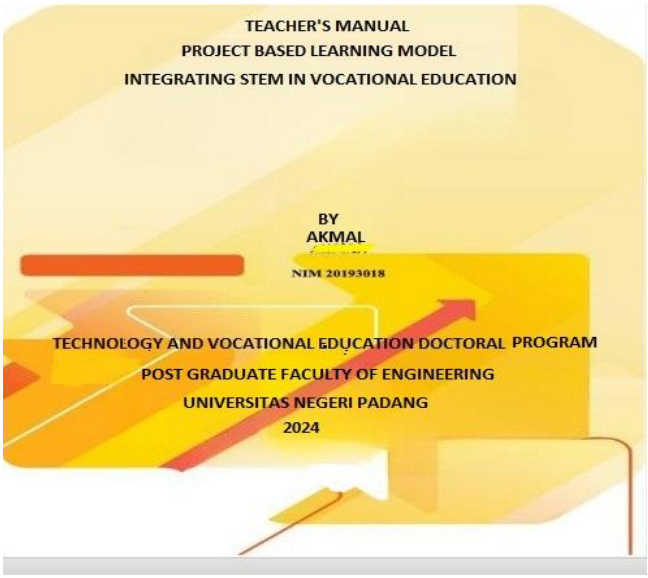

Figure 3: Teacher's Guide Cover

The student guidebook contains learning activities for students. It includes instructional guidelines, a guide for project-based learning activities integrated with STEM, conducting learning evaluations, student practice activity sheets, and others. The steps in the student guide are outlined.

Below is the design and plan of the student guide:

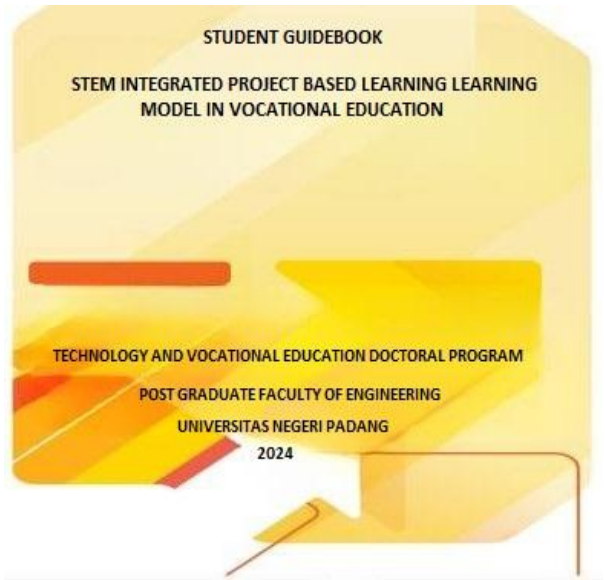

Figure 4: Student Guide Cover

Teaching Module

The teaching module for the Light Vehicle Power Transmission System is designed based on material according to the syllabus and relevant reference sources. This teaching module also includes evaluation sheets or exercises for students containing questions. The module is designed to be as engaging as possible to encourage students to learn independently and discover information. The design results of the teaching module are as follows:"

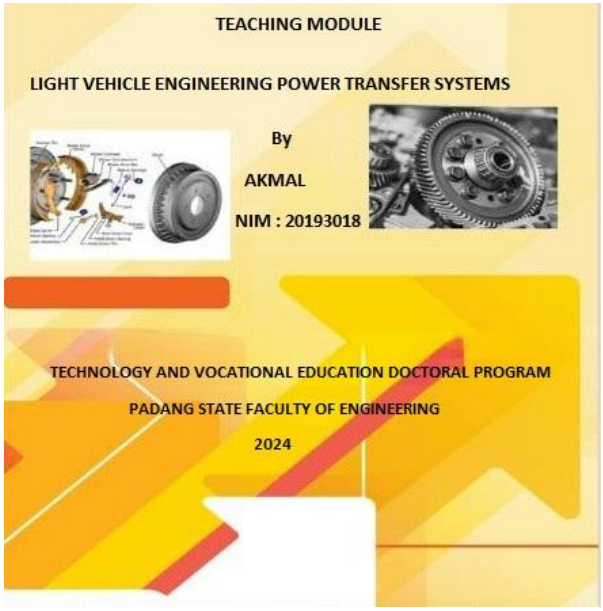

Figure 5: Teaching Module Cover

Stage 3: Model Development Stage

In this stage, the development of the *Project-Based Learning* model integrated with STEM for the subject of Light Vehicle Power Transmission Systems is carried out. The model development begins with the conceptual framework of the model, learning syntax, social systems, reaction principles, supporting systems, model impacts, and products.

The conceptual framework for the development of the PjBL-STEM learning model is in line with the *project-based learning* model that uses group learning. It indirectly refers to the *project-based learning* model integrated with STEM. The material taught by the teacher is the Light Vehicle Power Transmission System. The main activities in the Light Vehicle Engineering workshop are still conducted face-to-face with the *project-based learning* model integrated with STEM. The project-based learning model integrated with *STEM* has several components.

The placement of the model development variables adopts several relevant studies, the advantages, and intersections of the *project-based learning* model and the *STEM* concept that already exist, as well as adopting other relevant theories.

The contribution and novelty of this research provide a learning solution where the concept adopts the *PJBL* model and *STEM*. It has a *project-based learning* concept that uses group learning and is integrated with STEM, also applying the development of 21st-century technology by mastering critical thinking, collaboration, communication, and cooperation skills in learning. This model results in 7 syntax steps, which are: 1) Providing the problems to be faced, 2) Allowing students freedom, 3) Planning and developing the *project,* 4) Scheduling and monitoring the *project,* 5) Assessing the *project*, 6) Communication and reflection, 7) Providing rewards to students within the group.

The goal is to produce an effective learning model. The reaction principles in this model place the teacher as a facilitator, motivator, controller, supervisor, and guide in the learning process. The teacher is expected to provide reactions that allow students to actively participate in learning, accept and defend arguments, and collaborate within team groups. The social principles aim to enhance communication, respect for others' opinions, democracy, and cooperation. Additionally, it stimulates students' creativity in working on projects. Support systems, such as tools and materials, teaching modules, and student guidebooks, have also been prepared. The instructional impact is that students acquire knowledge, while the accompanying impact is that students become motivated, creative, and disciplined.

Stage 4: Validation and testing stage

At this stage, a *focus group discussion* (FGD) is conducted with experts to discuss the products that have been developed, including the syntax of the *project-based learning* model integrated with *STEM*, the model book, student guide, teacher guide, and teaching modules. The experts consist of five (5) individuals with relevant

expertise, including a language expert, a learning model expert, a learning media expert, and a subject matter expert. The experts also provide assessments and suggestions for the products that have been developed.

The following are the validation results on the product as follows:

The following are the syntax validation results of the integrated STEM *project based learning* model:

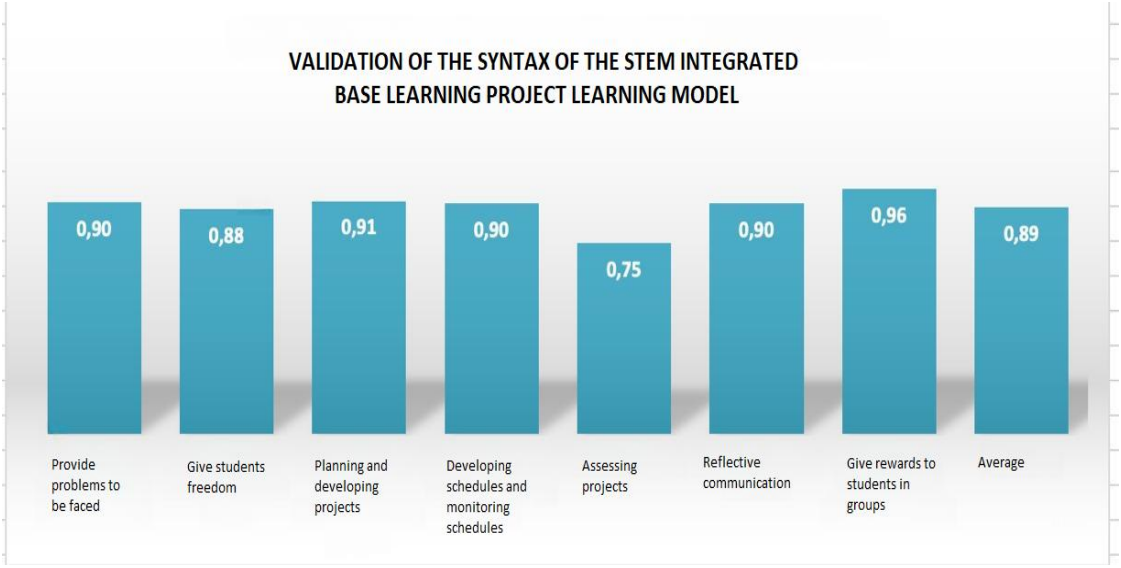

Figure 5: Model Syntax Validation Results

Based on the expert assessments presented in Table 4.4 for the syntax validation of the model, the results are as follows: 1) Providing the problems to be faced with an average score of 0.90, 2) Allowing students freedom with an average score of 0.88, 3) Planning and developing the project with an average score of 0.91, 4) Scheduling and monitoring the project with an average score of 0.90, 5) Assessing the project with an average score of 0.75, 6) Communication and reflection with an average score of 0.90, 7) Providing rewards to students within the group with an average score of 0.96. The overall result for the model syntax has an average score of 0.89. Since the result ≥ 0.667, it can be interpreted as having a sufficiently high coefficient, and thus the validity category is considered "valid. (Azwar, 2014:113).

The validation results of the model book are depicted in the following figure:

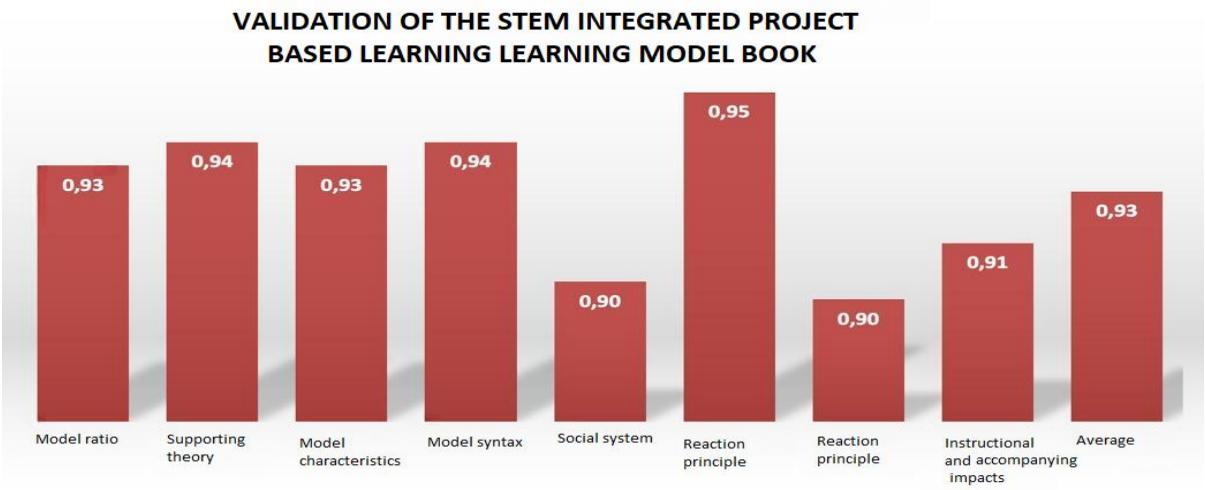

Figure 6: Model Book Validation Results

From Figure 5, the validation of the model book shows the following results: 1) The rational model has an average score of 0.93, 2) The supporting theory has an average score of 0.94, 3) The characteristics of the model have an

average score of 0.93, 4) The model syntax has an average score of 0.90, 5) The social system has an average score of 0.90, 6) The reaction principle has an average score of 0.95, 7) The supporting system has an average score of 0.90, 8) The instructional and accompanying impacts have an average score of 0.91. The overall average score for the model book validation is 0.90.

The results of the Teacher Guide Validation are depicted in the following picture:

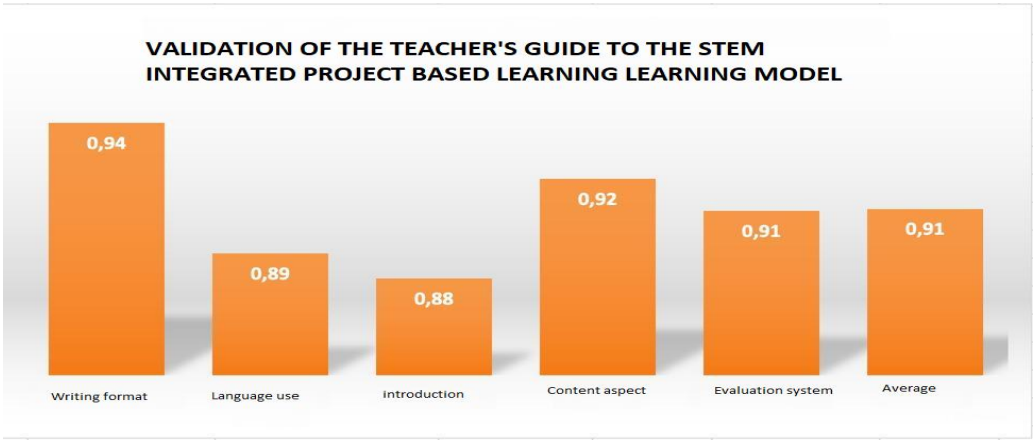

Figure 7: Teacher Guide Validation Results

Based on the expert assessments of the teacher's guide, the results are as follows: 1) The writing format has an average score of 0.94, 2) The language usage has an average score of 0.89, 3) The introduction has an average score of 0.88, 4) The content aspect has an average score of 0.92, 5) The evaluation system has an average score of 0.91. The overall average score for the validation of the teacher's guide is 0.91.

The results of the validation of the student guide are illustrated in the following figure:

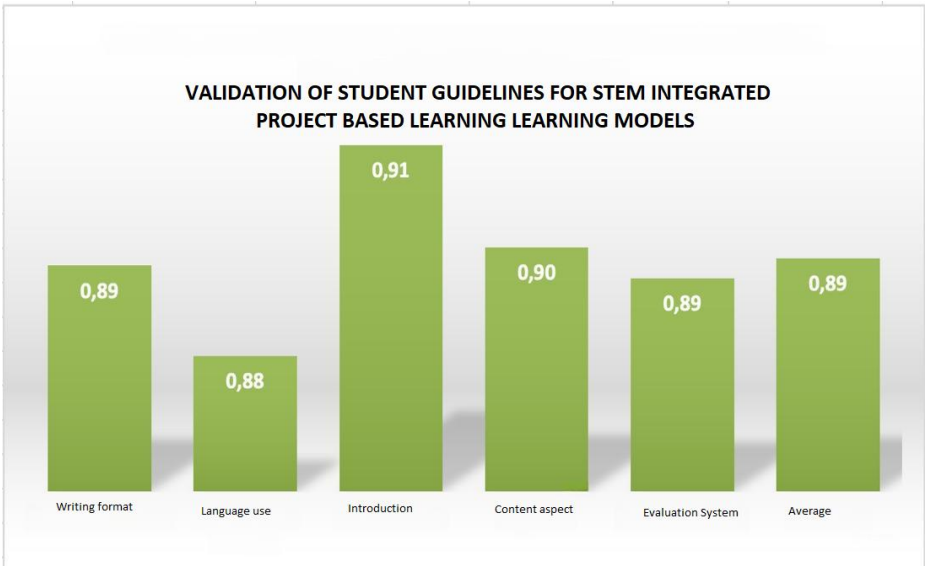

Figure 8: Student Guide Validation Results

Based on the expert assessments of the student guide, the results are as follows: 1) The writing format has an average score of 0.89, 2) The language usage has an average score of 0.88, 3) The introduction has an average score of 0.91, 4) The content aspect has an average score of 0.90, 5) The evaluation system has an average score of 0.89. The overall average score for the validation of the student guide is 0.89.

The results of the validation of the teaching module are depicted in the graph as follows:

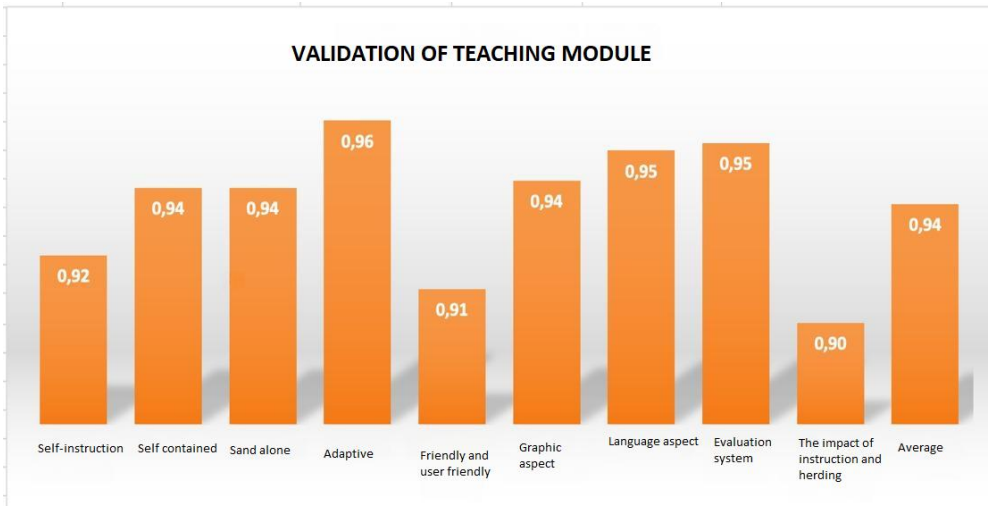

Figure 9: Student Guide Validation Results

The results of the validation of the teaching module are as follows: 1) Self Instruction has an average score of 0.92, 2) Self Contained has an average score of 0.94, 3) Stand Alone has an average score of 0.94, 4) Adaptiveness has an average score of 0.96, 5) Being Friendly and User-Friendly has an average score of 0.91, 6) Graphic Aspects have an average score of 0.94, 7) Language Aspects have an average score of 0.95, 8) The Evaluation System has an average score of 0.95, 9) Instructional and Accompanying Impacts have an average score of 0.90. The overall average score for the validation of the teaching module is 0.94.

The practicality testing aims to determine the usability of the developed product and model that will be used by students and teachers, to see if they are practical and easy to use. Students and teachers are involved in providing assessments and suggestions for improvements regarding the use of the model, student guide, teacher guide, and teaching module. Below are the results of the practicality testing of the product.

The results of the teacher's practical test can be depicted in the picture:

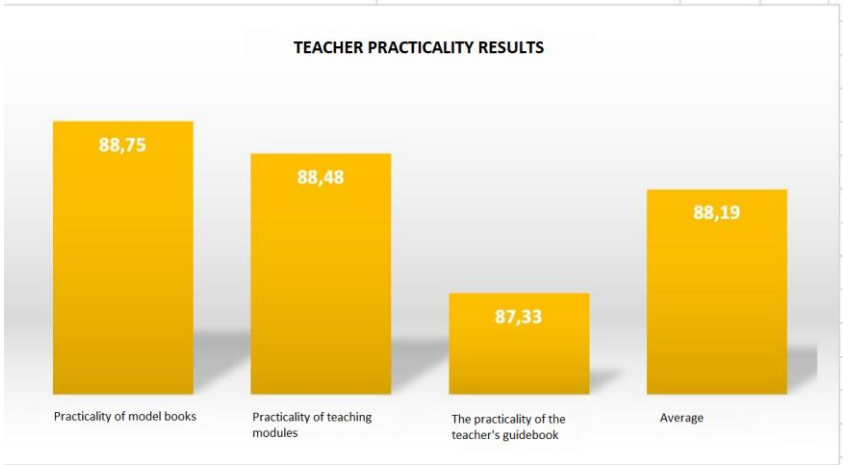

Figure 10: Teacher Practicality in STEM-integrated *project based learning* model products

From the results shown in Figure 9, it can be seen that the practical test of the *Project-Based Learning* model integrated with STEM consists of: 1) The model book has an average score of 88.75, 2) The teaching module has an average score of 88.48, 3) The teacher guide has an average score of 87.33, and 4) The overall average score of the product is 88.19. These practicality results show (Purwanto, 2009) that a score range of 80-89 is interpreted as practical. It can be concluded that the product falls into the "very practical" category and can be used.

The results of students' practical tests can be depicted in the picture:

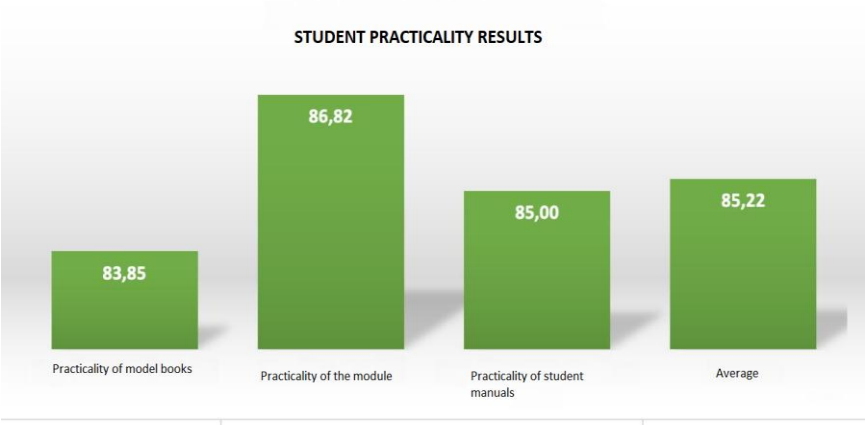

Figure 11: Students in STEM-integrated project based learning model products

Based on the results of the practical test of the product on students, the *Project-Based Learning* model integrated with STEM shows the following: 1) The model book has an average score of 83.85, 2) The teaching module has an average score of 86.82, 3) The student guide has an average score of 85, and 4) The overall average score of the product is 85.22.

In conclusion, the *Project-Based Learning* model integrated with STEM for the subject of Light Vehicle Power Transmission Systems has been proven to be valid and practical. The supporting products produced include the model book, teaching module, teacher guidebook, and student guidebook.

CONCLUSION

The conclusion from this finding is that the *Project-Based Learning* model integrated with STEM for the subject of Light Vehicle Power Transmission Systems has a *project-based learning* concept that uses group learning. It indirectly refers to the *project-based learning* model integrated with STEM, which also incorporates 21st-century technological advancements by mastering competencies in critical thinking, collaboration, communication, and cooperation in learning. The products produced include the model book, teaching module, teacher guide, and student guide. This model produces 7 syntax steps, which consist of: 1) Providing the problems to be faced, 2) Allowing students freedom, 3) Planning and developing the project, 4) Scheduling and monitoring the project, 5) Assessing the project, 6) Communication and reflection, 7) Providing rewards to students within the group. The developed learning model has also been proven to be valid and practical, thus can be used. The recommendation from this finding is that it is hoped to be applied to other subjects, and further research can be conducted by adding other variables. Teachers must understand the concept of project-based learning and STEM, which requires time to study in more depth. There is a need to stimulate and motivate students in applying this learning model, so that the learning process can be focused, effective, and efficient.

REFERENCES

[1] Ayuso, A., Merayo, N., Ruiz, I., & Fernández, P. (2022). Challenges of STEM vocations in secondary education. IEEE Transactions on Education, 65(4), 713-724.

[2] Akgunduz, D., & Mesutoglu, C. (2021). STEM education for Industry 4.0 in technical and vocational high schools: Investigation of teacher professional development. Science Education International, 32(2), 172-181.

[3] Azwar, S. 2014. *Reliabilitas dan Validitas*. Yogyakarta: Pustaka Pelajar.

[4] Chondrogiannis, E., Symeonaki, E., Papachristos, D., Loukatos, D., & Arvanitis, K. G. (2021). Computational thinking and STEM in agriculture vocational training: A case study in a Greek vocational education institution. European Journal of Investigation in Health, Psychology and Education, 11(1), 230-250.

[5] Emzir. 2013. *Metodologi Penelitian Pendidikan: Kuantitatif dan Kualitatif*. Jakarta: PT Raja Grafindo Persada, 2013.

[6] Hidayatuloh, M. K. Y., & Muslim, S. (2021, March). Absorption level vocational high school graduates in

industrial. In Journal of Physics: Conference Series (Vol. 1833, No. 1, p. 012019). IOP Publishing.

[7] Indrawan, E., Jalinus, N., & Syahril. (2019). Review Project Based Learning. *International Journal of Science and Research*, *8*(4), 1014–1018.

[8] Karnando, J., Rezki, I. K., & Tasrif, E. (2021). Efektivitas E-Modul Berbasis Project Based Learning Selama Pembelajaran Jarak Jauh. *JAVIT : Jurnal Vokasi Informatika*, 1–4. https://doi.org/10.24036/javit.v1i1.17.

[9] Kamaludin, N., Abdullah, A. G., & Komaro, M. (2022, March). Competency Demands of Vocational High School Graduates in the Era of the Industrial Revolution 4.0. In 4th International Conference on Innovation in Engineering and Vocational Education (ICIEVE 2021) (pp. 51-56). Atlantis Press.

[10] Made, A. M., Ambiyar, A., Riyanda, A. R., Sagala, M. K., & Adi, N. H. (2022). Implementasi Model Project Based Learning (PjBL) dalam Upaya Meningkatkan Hasil Belajar Mahasiswa Teknik Mesin. *Edukatif : Jurnal Ilmu Pendidikan*, *4*(4), 5162–5169. https://doi.org/10.31004/edukatif.v4i4.3128.

[11] Muslim, M., Ambiyar, A., Setiawan, D., & Putra, R. (2020). Developing project-based learning tools for light vehicle engine maintenance subjects at vocational high school. *Jurnal Pendidikan Vokasi*, *10*(1), 22-33.

[12] Mulyani, T. (2019). Pendekatan pembelajaran STEM untuk menghadapi revolusi industry 4.0. In Prosiding Seminar Nasional Pascasarjana (Vol. 2, No. 1, pp. 453-460).

[13] Nurtanto, M., Sudira, P., Kholifah, N., Samsudin, A., & Warju, W. (2020). Vocational Teachers' Perceptions and Perspectives in the Implementation of STEM Learning in the 21st Century. Online Submission, 9(4), 1675-1680.

[14] Nurtanto, M., Pardjono, P., & Ramdani, S. D. (2020). The effect of STEM-EDP in professional learning on automotive engineering competence in vocational high school. Journal for the Education of Gifted Young Scientists, 8(2), 633-649.

[15] Nuryanto, A., & Eryandi, K. Y. (2020, February). The 21st century ideal skills for vocational high schools. In International Conference on Educational Research and Innovation (ICERI 2019) (pp. 142-147). Atlantis Press.

[16] Permanasari, A. (2016, October). STEM education: Inovasi dalam pembelajaran sains. In Seminar Nasional Pendidikan Sains VI 2016. Sebelas Maret University

[17] Purwanto. (2009). Evaluasi Hasil Belajar. Yogyakarta: Pustaka Belajar.

[18] Ridha, M. R., Zuhdi, M., & Ayub, S. (2022). Pengembangan perangkat pembelajaran PjBL berbasis STEM dalam meningkatkan kreativitas fisika peserta didik. Jurnal Ilmiah Profesi Pendidikan, 7(1), 223-228.

[19] Ummah, S. K., In'am, A., & Azmi, R. D. (2019). Creating Manipulatives: Improving Students' Creativity through Project-Based Learning. *Journal on Mathematics Education*, *10*(1), 93-102.

[20] Wannapiroon, P., Nilsook, P., Techakosit, S., & Kamkhuntod, S. (2021). STEM Literacy of Students in Vocational Education. International Journal of Technology in Education and Science, 5(4), 527-549.