Development Of Digital Learning Modules For Engineering Physics Course: A Hots-Oriented Approach

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Abstract. This study aims to develop a digital learning module for the Engineering Physics course in the Department of Mechanical Engineering Education, Universitas Negeri Medan. The learning process has traditionally been lecture-based, limiting student engagement and critical thinking. In line with the Merdeka Belajar-Kampus Merdeka (MBKM) curriculum, students are expected to produce Higher Order Thinking Skills (HOTS)-oriented outputs. This research employed the Dick and Carey model of instructional design in three stages: planning and formulation of objectives, module development, and formative evaluation. The module was validated by experts in materials, media, and instructional design, and further tested through one-to-one, small group, and field trials. Results indicate the module is feasible and effective, improving student learning outcomes by 81.92% as shown by the difference between pre-test and post-test scores. The developed digital module can serve as an innovative teaching material to enhance student-centered learning in engineering education.

Keywords: Engineering physics; Higher Order Thinking Skills (HOTS); E-Module; Digital learning; Teaching materials.

1. Introduction

Education serves as a medium for transforming science and technology for the benefit of human life. Mastery of science and technology is considered a key requirement to obtain opportunities and adapt to the dynamics of an ever-evolving global society (Tilaar, 2012). In this context, human resources become the main asset in mastering science and technology. The quality of human resources can only be achieved through improving the quality of education, especially in higher education institutions.

As a provider of skilled graduates, higher education is expected to produce individuals who are qualified and able to compete in the global era. Therefore, systematic and scientific studies are required in order to implement effective and efficient education, particularly through the integration of educational technology and media. One of the learning orientations emphasized in recent years is the development of Higher Order Thinking Skills (HOTS), which aim to prepare students to not only adapt but also create and innovate in facing global challenges (Fuaddilah Ali Sofyan, 2019).

The learning process is essentially a communication process between educators and students, which necessitates the use of effective learning media. In line with the rapid advancement of

science and technology, particularly in the field of information and communication technology, the role of computer-based media in learning becomes increasingly significant. Effective learning media must be attractive, easy to understand, memorable, practical, and able to enhance interaction between lecturers and students (Sudarwan Danim, 2010). However, in practice, the learning process in certain courses, such as Engineering Physics, often remains conventional, monotonous, and less engaging, resulting in limited student creativity and learning achievement (Yaumi, 2014).

To address these challenges, the integration of digital modules emerges as an innovative solution. Digital learning resources provide practical benefits, as they can be accessed through various devices, are environmentally friendly, and offer flexibility in their use (Simonson, 2014). Moreover, the development of digital modules follows a systematic instructional design process, such as the model proposed by Dick & Carey (2005), ensuring that learning objectives are achieved through structured planning and development.

Based on these considerations, this research focuses on the development, feasibility, and effectiveness of digital modules in the Engineering Physics course within the Department of Mechanical Engineering Education. The use of digital modules is expected to not only enhance student engagement and learning outcomes but also contribute to improving graduate competencies in line with the demands of the world of work.

2. Literature

Learning Models

The development of learning media has been widely discussed in educational research. Gustafson and Branch (2019) emphasized that learning media development consists of at least five core activities: analyzing learners' needs, designing effective and efficient specifications, developing learning materials, implementing instructional design, and conducting formative and summative evaluations. This view aligns with the constructivist approach, which considers learning as an active process of knowledge construction (Byrnes, 2019). Among various instructional design models, the Dick and Carey model is recognized for its systematic and comprehensive steps in instructional development (Dick & Carey, 2012). In this study, the Dick and Carey model serves as the primary framework for digital module development.
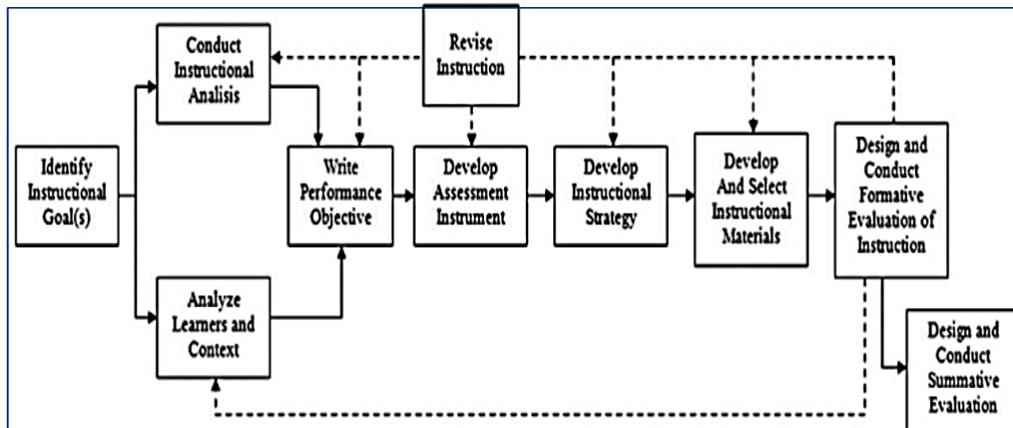
Figure 1. Dick and Carey models (Dick and Carey, 1996)[13]

Digital Modules

The transition from print-based to digital-based learning resources marks a significant transformation in educational technology. Haritz (2013) defined digital modules as publications that consist of text, images, and sounds in digital format, accessible through computers or electronic devices. Similarly, Sitepu (2006) described e-books and e-modules as digital representations of teaching materials recorded electronically for flexible use. Digital modules are designed as independent learning resources, enabling students to study systematically, either individually or collaboratively (Kadek, 2016). Furthermore, Anwar (2010) outlined the essential characteristics of learning modules, including self-instructional, self-contained, stand-alone, adaptive, user-friendly, and consistent. These characteristics are also embedded in digital modules, making them effective tools for student-centered learning.

Higher Order Thinking Skills (HOTS)

HOTS represents an educational reform paradigm that emphasizes critical, creative, and problem-solving skills. (in Sofyan, 2019) described HOTS not merely as a questioning model but as a learning approach that integrates critical thinking and problem-solving into both teaching and assessment processes. Lewis and Smith (in Sani, 2019) highlighted that high-level thinking emerges when learners connect new and existing knowledge to develop alternative solutions to complex problems. Nugroho (2018) further defined HOTS as a non-algorithmic process that engages learners in new challenges requiring critical and creative application of knowledge. Collectively, these studies affirm that HOTS-oriented learning is essential in equipping students with advanced cognitive skills beyond memorization, focusing instead on evaluation, analysis, and innovation.

Engineering Physics Course

The Engineering Physics course is a compulsory subject in the Department of Mechanical Engineering Education, weighted at 3 credits. The course emphasizes HOTS-oriented learning and focuses on systematic learning design, covering areas such as theories of learning, instructional models, and learning design frameworks. However, preliminary observations have indicated that current instructional practices in Engineering Physics often rely on conventional

and monotonous approaches, limiting students' creativity and engagement. Thus, integrating digital modules in this course is expected to provide innovative solutions that enhance both learning experiences and outcomes.

Research Roadmaps

Institutional research roadmaps serve as strategic guidelines for aligning academic activities with global and national challenges. The Faculty of Engineering at Medan State University has designed a roadmap centered on vocational education, industrial engineering, and digital technology within the framework of the Industrial Revolution 4.0. This roadmap integrates three approaches: basic research for theoretical advancement, applied research for practical problem-solving, and research and development for product innovation. At the program level, the Mechanical Engineering Education Study Program emphasizes vocational education development, technological innovation, industrial problem-solving, and technology application.

At the individual level, lecturers are guided by a research roadmap that emphasizes adaptation to local and global issues, inter-sector collaboration, and impactful outputs in the form of publications, innovative products, or implementation models. Collectively, these roadmaps underscore the commitment to strengthening research integration, collaboration, and contribution to societal and industrial development.

3. Methodology

Types and Research Design
This study employed a Research and Development (R&D) approach, which is commonly used to develop and validate educational products such as textbooks, learning media, and digital modules. The R&D process includes several stages: product development, expert validation, field trials, revision, and final evaluation. This study specifically applied the learning development framework adapted from the Dick and Carey instructional design model, which provides systematic steps for analyzing, designing, developing, implementing, and evaluating learning products.

Research Flow
The research flow was structured with reference to the Dick and Carey model, beginning with needs analysis, setting learning objectives, developing instructional strategies, and culminating with formative and summative evaluation. This systematic sequence ensures that the digital module produced is both feasible and effective for use in the Engineering Physics course.

Research Location and Time
This research was conducted in the Department of Mechanical Engineering Education, Faculty of Engineering, State University of Medan. The sample consisted of 60 students from the 2023 cohort of the study program. The research was carried out over one semester, from February to August 2025.

Research Instruments and Data Collection
Data were collected through expert validation questionnaires, student response questionnaires, and pre-test and post-test assessments. The instruments consisted of evaluation sheets for

material experts, media experts, and learning design experts, which were used to determine the validity and feasibility of the developed digital module.

The steps for data collection and analysis were as follows:

1. Conduct validation by material experts, media experts, and learning design experts.
2. Review and revise the module based on expert feedback.
3. Quantify expert assessments according to predetermined scoring criteria.
4. Tabulate expert validation results.
5. Distribute student response questionnaires after the trial implementation.
6. Quantify questionnaire responses and tabulate data.
7. Analyze data using descriptive statistics to determine feasibility.

Where:

$$\mathbf{\bar{X}} = \frac{\sum X}{N}$$

X   = Qualifying score Coursware
$\sum X$ = Total score of each subvariable
N   = Number of sub variables

The interpretation of validation results was based on the following scoring scale (Table 1).

Table 1. Interpretation of Digital Module Validation

No	Score Interval	Interpretation
1	1.00 – 2.49	Invalid
2	2.50 – 3.32	Quite Valid
3	3.33 – 4.16	Valid
4	4.17 – 5.00	Highly Valid

Effectiveness Analysis

The effectiveness of the digital module was analyzed by comparing pre-test and post-test scores of students. The pre-test consisted of multiple-choice items with four alternatives, administered before the learning process using the digital module. The post-test, with a similar structure, was conducted after students completed the learning activities with the module.

According to Wotruba and Wright (in Miarso, 2017), indicators of effective learning include: well-organized material, effective communication, mastery of subject matter, positive teacher-student interaction, fairness in assessment, flexibility in instructional strategies, and improved student learning outcomes. In this study, effectiveness was measured through the increase in test scores from pre-test to post-test, which reflected the impact of the developed digital module on student learning achievement.

4. Results and Discussion

4.1 Preliminary Research

The research was initiated with classroom observations in the Department of Mechanical Engineering, State University of Medan, followed by a Focus Group Discussion (FGD) with four lecturers of the Engineering Physics course. Observations revealed several issues such as

the lack of HOTS-based learning materials, limited use of evaluation sheets, unavailability of digital modules, and low student engagement in classroom discussions (Table 2).

Table 2. Preliminary Research Observation Results

Yes	Observation Aspect	Description
1	Number of students in 1 (one) class	Observations in the field show that students who take the Learning Design course are 30 - 35 people.
2	Cumulative Grade Point Average (GPA)	Based on data from the academic section of the Mechanical Engineering Education department of Unimed, information was obtained that the average GPA of students who took the Learning Design course was 2.71.
3	Origin of SMK/SMA/MA	From high school, 24 students (66.6%) came from vocational schools and 12 people (33%) came from high school and came from Madrasah Aliyah (MA) totaling 0%. There are more students from vocational schools when compared to students from high school and MA.
4	Number of credits/ meeting	Learning activities for the Learning Design course with a weight of 2 credits, are carried out consisting of 16 meetings, with details of 14 meetings for the presentation of material and 1 meeting for midterm exams and 1 meeting for the final semester exam
5	Supporting references for Learning Design courses	The supporting references available in the library are mostly in foreign languages, and still discuss Learning Design in general, while references in the form of digital modules are not yet available.

6	Lecture process in class	a. Lecturers do not conduct an initial test of students' abilities at the beginning of Learning Design learning activities (0%)
		b. During the Learning Design learning activities, there were no (0%) lecturers who used K3 learning textbooks. Lecturers provide material only in the form of *handouts* that are distributed to students at each meeting.
		c. The learning strategies used in the classroom have not fully consisted of an introduction, presentation and conclusion.
		d. The learning method used by lecturers is generally in the form of lectures and questions and answers, and is followed by discussions and assignments.
		e. Students are less active in asking questions about problems that arise, only about 5% of the total number of students who actively ask questions.
		f. Tasks are given individually or groups, questions are made spontaneously which sometimes do not match the material and questions have not come from the question bank because the question bank is not yet available.
		g. Students in general are less interested in taking the Learning Design course, where the observation results show that students are less enthusiastic and inactive in asking or answering questions asked by lecturers, even though in terms of student attendance is quite high.
		h. Reading and studying lecture material in the form of *handouts* is still low and less serious, this can be seen when receiving *the handout* does not try to make a summary or small notes

The FGD confirmed these findings, highlighting the need for (1) HOTS-oriented content, (2) varied presentation methods (lectures, interactive Q&A, group discussion), (3) the development of innovative digital modules, and (4) systematic evaluation through pre-test and post-test (Table 3). These inputs formed the foundation for developing the digital module prototype.

Table 3. Learning Conditions Preliminary Results

Yes	Previous/Current Learning Conditions	Required Learning Conditions
1	Learning outcomes and competencies are not in accordance with student needs and are not HOTS-based	Learning outcomes and competencies are adjusted to the needs of HOTS-based students
2	Not using evaluation sheets in assessing the learning process	Using evaluation sheets in assessing the learning process

3	Learning media is difficult to access, inadequate because it is incomplete and not yet in digital form	Providing digital modules that can be accessed easily, complete and attractive.
4	Learning activities have no introduction, presentation and conclusion	Learning activities are adjusted to learning strategies, namely introduction, presentation and closing and based on HOTS
5	The initial test of students' ability was not carried out	Conduct an initial test of students' abilities
6	Students and lecturers stated that it is necessary to develop the learning media of the Learning Design course	The development of learning media in the form of a digital module for the HOTS-based Learning Design course was carried out

4.2 Expert Validation Results

The feasibility of the digital module was assessed through expert validation:

- Learning Design Expert: Average score 4.1 (82%), indicating "Valid". Suggestions included adding chapter summaries, templates for final assignments, and expanded assessment tools.

- Material Expert: Average score 4.25 (85%), indicating "Highly Valid". Recommendations included revising cover design, adding a detailed narrative on the back cover, and enhancing illustrations.

- Media Expert: Average score 4.3 (86%), indicating "Highly Valid". Feedback emphasized improving layout readability, using consistent colors, and adding more representative illustrations.

The combined validation result yielded an overall feasibility score of 4.22 (84%), categorized as "Highly Valid". Engineering Physics textbooks, with illustrations added that describe the characteristics and relate to the content (material) of the book;
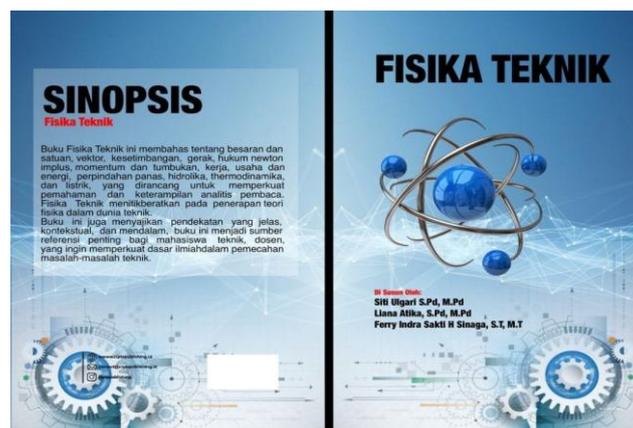

Figure 2. Product Book Cover After Qualification By Expert

4.3 Effectiveness of the Digital Module

The digital module was evaluated through one-to-one testing, small group trials, and field trials:

1. One-to-one Trial (3 students): Average score 4.0 (82%). Inputs included fixing typographical errors, enlarging chapter titles, and improving illustration sources.

2. Small Group Trial (12 students): Average score 4.38 (85%). Suggestions involved adding full-color illustrations, designing a more informative back cover, and adjusting page numbering.

3. Field Trial (30 students): Observations showed that preliminary, presentation, and closing activities followed the designed model. Student participation increased during interactive Q&A, group discussion, and presentation activities. Pre-test and post-test results demonstrated significant improvement: average pre-test 41.12 and post-test 74.80, with an increase of 33.69 points (81.92%).

These findings align with Suparman (2012) and Miarso (2017), affirming that effective learning materials improve student outcomes through well-structured instructional design.

4.4 External Outputs and Achievements

The research generated several mandatory outputs:

a. Final report uploaded in SIMPPM UNIMED.
b. Digital module published by Cipta Media Nusantara.
c. Accepted publications in ICIESC 2025 International Conference and VANOS Journal (Sinta 4).
d. Research report registered in SIMHAKI UNIMED. Additionally, ISBN-registered printed books and intellectual property rights were also secured.

4.5 Future Plans

Planned activities for the following months (September–December 2025) include: finalizing conference papers, compiling financial reports, managing research copyright (HAKI), and presenting findings in the Research Results Seminar.

5. Conclusion

This study shows that the development of the Engineering Physics Digital Module has gone through a systematic process—starting from needs analysis, expert validation, small trials, to field implementation. The results confirm that the module is both feasible and effective in supporting student learning. Expert validation rated it in the highly valid category, while learning outcomes improved significantly, with students' average scores rising from 41.12 (pre-test) to 74.80 (post-test).

In practice, this digital module not only provides structured and accessible learning materials but also encourages more active student participation in discussions, presentations, and

collaborative learning. These findings underline the importance of continuously improving digital-based learning resources to meet the needs of both lecturers and students.

In the future, lecturers are encouraged to keep refining the use of this module, while study programs can expand its application through training and integration into curriculum design. For researchers, this work can serve as a foundation to further explore the development of digital learning media on a wider scale.

References

[1] A. Haritz, *Digital Module Development in Educational Technology*. Jakarta: Prenadamedia, 2013.

[2] A. Lewis and D. Smith, "Defining Higher Order Thinking," in R. A. Sani, *HOTS-Based Learning*. Tangerang: Tira Smart, 2019.

[3] A. Suparman, *Desain Instruksional Modern*. Jakarta: Erlangga, 2012.

[4] B. P. Sitepu, *Penulisan Buku Teks Pelajaran*. Bandung: Remaja Rosdakarya, 2006.

[5] Collins, J., Hammond, M., Wellington, J.: *Teaching and Learning with Multimedia*. Routledge, New York (1997).

[6] Dick, W. (1996). The Dick and Carey model: Will it survive the decade?. *Educational technology research and development*, *44*(3), 55-63.

[7] Dick, W and L. Carey, *The Systematic Design of Instruction*. 6th ed. Boston: Pearson, 2005.

[8] Dick W, L. Carey, and J. O. Carey, *The Systematic Design of Instruction*. 7th ed. Boston: Pearson, 2012.

[9] Gustafson, K. L., Branch, R. M.: S*urvey of Instructional Development Models. Eric Clearinghouse on Information & Technology*, Syracuse University, New York (2012).

[10] I. Anwar, Pengembangan Bahan Ajar. Bandung: Alfabeta, 2010.

[11] J. P. Byrnes, *Cognitive Development and Learning in Instructional Contexts*. 4th ed. Boston: Pearson, 2019.

[12] Miarso, Y.: *Instructional Development Model Survey*. Postgraduate University of Jakarta, Jakarta (2017).

[13] Nugroho, A.: *HOTS Higher Level Thinking Ability: Assessment Learning Concepts and Questions*. Gramedia Widiasarana Indonesia, Jakarta (2018).

[14] Sofyan, F. A.: *Implementation of HOTS in the 2019 Curriculum*. Inventa Journal (2019).

[15] Sani, R. A.: HOTS-Based Learning. Tira Smart, Tangerang (2019).

[16] Schwier, R. A., Misanchuk, E. R.: *Interactive Multimedia Instruction. Educational Technology Publications*, Inc., New Jersey (2013).

[17] S. Danim, *Media Komunikasi Pendidikan*. Jakarta: Bumi Aksara, 2010.

[18] Seels, B. B., Richey, R. C.*.: Learning Technology: Its Definition and Control*. IPTPI, Jakarta (2012).

[19] Simarmata, J., Mujiarto.: *Multimedia Learning*. Alphabet (2019).

[20] Simonson, M. R., Thompson, A.: *Educational Computing Foundations (2nd ed.).* Merrill Publishers, Columbus (2014).

[21] S. Kadek, "Development of Digital Modules as Independent Learning Resources," *Jurnal Pendidikan Teknologi*, 2016.

[22] Tilaar, H. A. R. (2012). *Perubahan Sosial dan Pendidikan*. Jakarta: Rineka Cipta.

[23] Williams, N.: *Educational Multimedia: Where's the Interaction*. IT for Learning (2015).

[24] Yaumi, M. (2014). *Principles of instructional design aligned with the 2013 curriculum*. Jakarta: Prenadamedia Group.

[25] Y. Miarso, *Model Pengembangan Instruksional*. Jakarta: Universitas Negeri Jakarta, 2017.