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Development of STEM-based Science E-Module on the Human Excretory System Topic

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Abstract: Teachers generally lack sufficient knowledge about STEM approaches, so teachers have difficulty developing STEM-based modules. Our research aims to develop a STEM-based science e-module on the human excretory system topic that is suitable for use by junior high school students. We use a type of research and development (R&D) concerning the Borg & Gall development model modified by Palilingan. Data collection techniques using interviews and questionnaires. The research instruments used interview sheets, product validation questionnaires, and product practicality questionnaires. The results showed that: (1) the validity test by learning media experts obtained a score of 98.33% and was included in the very valid category (no need for revision); (2) the validity test by subject matter experts shows a value of 99.17% and is included in the very valid category (no need for revision); and (3) limited trials in small groups show a value of 93.40% and are included in the very practical category. Based on the research that has been done, the STEM-based science e-module on the human excretory system topic that is suitable for use by junior high school students is appropriate for use by junior high school students.

Keywords: E-module; Human excretory system; Science learning; STEM approach

Introduction

In the 21st century, technology plays an important role in our daily lives. It calls professionals, educators, and students to reflect on their basic beliefs to use technology to redesign or re-engineer existing educational systems (Kumar Basak et al., 2018). Education continues to develop along with the development of science and technology. Following up on technological developments that can be utilized in education, there is one factor in the development of the current education curriculum in Indonesia, namely the 2013 curriculum. The government's 2013 curriculum provides a policy that learning must be designed in an interesting, holistic, and motivating way for students (Fahmy et al., 2015; Rahmawati et al., 2022). The 2013 curriculum is implemented using a scientific approach that applies three domains in learning: attitudes, knowledge, and skills (Wina et al., 2017). In this case, previously teacher-centered learning is now regulated to be student-centered.

Learning can be integrated with information and communication technology (ICT) (Dziuban et al., 2018). The integration of ICT in education generally means a technology-based teaching and learning process closely related to the use of learning technology in schools (Ghavifekr & Rosdy, 2015). Technology in education helps learning activities develop, process, and present material so that learning is more effective, efficient, and easily accessible to people who are learning (Ally et al., 2014; Darmayasa et al., 2018). Technology creates a learning atmosphere that can attract students' interest and motivation to learn (Aremu & Efuwape, 2013).

Science is one of the main subjects in the education curriculum in Indonesia, including at the junior high school level (Suryawati & Osman, 2017). Science spans several disciplines (astronomy, biology, earth sciences, engineering, and spectacles), and each discipline within

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science involves its processes, insights, analytical techniques, and ways of concealing phenomena (Bathgate et al., 2014). Science is a subject related to natural phenomena and characteristics of the surrounding environment, which are obtained systematically and can be applied in everyday life, both for the environment and for technology (Lestari et al., 2022; Wola et al., 2023). Science learning is a study of humans or the problems of how humans develop a better life (Safitri & Rungkat, 2021; Suriani et al., 2022). Science learning is expected to help students understand natural phenomena (Lederman et al., 2014; Ruitan et al., 2023).

Natural science is very important to study because it is closely related to everyday life. One topic that is closely related to students' daily lives is the topic of the human excretory system. This topic contains excretory organs in the body and their functions that are difficult to study (Elci et al., 2021; Pada et al., 2021; Tegine & Rungkat, 2022). The excretory system learns about the disposal of metabolic waste products through toxic compounds such as CO_2, H_2O, sweat, urine, bile, and feces (Djamahar et al., 2020). Furthermore, they stated that learning with a student-centered approach was recommended to achieve learning objectives on the topic of the excretory system. Rusdi et al. (2023) wrote that learning biology in the 21st century requires students to understand concepts, including learning the excretory system. Ristanto et al. (2021) stated that the excretory system must be taught through constructivism so that conceptual understanding can be built properly and students can apply their knowledge in everyday life.

In recent years, learning, media, and technology have become key publications for critical studies in education and technology (Williamson et al., 2020). Using information technology by educators in learning can facilitate the absorption of lesson content so that student understanding increases. The development of learning media is divided into print, visual, audio-visual, and computer or electronic media (Komisesari et al., 2020). Electronic media can make the learning process more interesting and interactive, can be done anytime and anywhere, and can improve the quality of learning. Educators in the 21st century must be able to facilitate student learning through various educational technology innovations, one of which is an electronic module (Nesri & Kristanto, 2020).

An electronic module (e-module) is a form of independent teaching material arranged systematically in easy-to-understand language into the smallest learning units, presented in an electronic format equipped with animation, audio, and video, making the user more interactive with the program (Irfan et al., 2019; Ravista et al., 2021). E-modules provide individual instruction and provide feedback to show students' learning strengths and weaknesses through evaluation and help to focus on difficult concepts (Kalathingal & Buchanan, 2017). The characteristics of electronic modules as above need to be owned by students because electronic modules have the potential to increase student learning motivation (Wiyoko et al., 2014). Giving motivation is very important to encourage students to be actively involved in learning (Gani et al., 2022).

Various previous studies have shown that presenting a science, technology, engineering, and mathematics (STEM) approach to science learning is important. The STEM approach can shape students into human resources who can think critically and creatively, systematically and logically to meet 21st century human resource standards and face increasingly complex global challenges. The results of research by Anggraini et al. (2017) show that several basic competencies in science subjects at the junior high school level can be integrated with the STEM approach. On the other hand, research by Diana et al. (2021) reported that most of the teachers did not have adequate knowledge about STEM, so teachers had difficulties in developing STEM-based modules. Align with research by Shernoff et al. (2017), who wrote that many teachers are interested in the STEM approach but are still determining if they are ready to implement it. Burrows et al. (2015) stated that there is much hope regarding the STEM approach to help the next generation of students solve real-world problems by applying interdisciplinary concepts as well as capacities for critical thinking, collaboration, and creativity.

Based on the author's interviews with science teachers at SMP Negeri 2 Tondano, it is known that in teaching, the teacher uses the lecture method very often, prioritizes the use of printed books, makes presentations using power point, has never used interactive media, and is not familiar with STEM learning. On the other hand, students generally can use computers and are accustomed to using smartphones. In addition, student mastery of the topic of the human excretory system is still standard. A lack of interactive learning media can make learning less meaningful, not challenging, and boring. Research by Sari et al. (2022) succeeded in developing a STEM-based science module but in printed form. These products are more effective when made in electronic form to save paper use, are not bound by place and time, and are easily accessible to students at any time. In association with the things disclosed before, we need innovations in science learning. Our research aims to develop a STEM-based science e-module on the human excretory system topic that is suitable for use by junior high school students.

Method

This type of research is research and development (R&D). The development model refers to Borg and Gall, modified by Palilingan (2014). The research steps include 1) planning, 2) exploratory study, 3) initial form development, 4) data collection and analysis instruments, 5) validation (expert validation and field testing), 6) revision based on validation results, and 7) socialization product (see Figure 1).

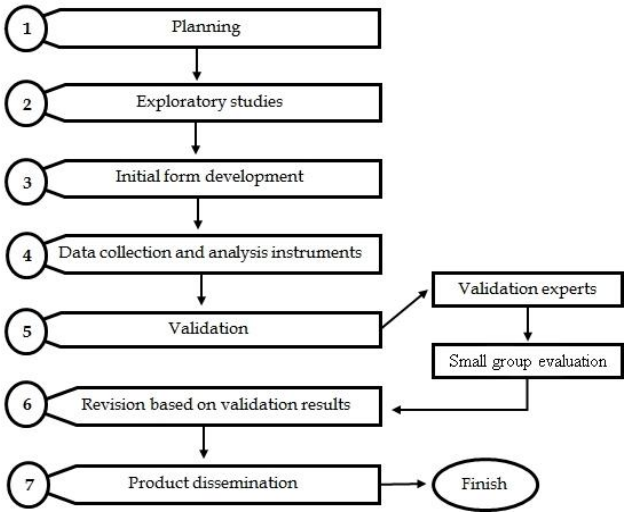

Figure 1. Research flowchart

The subjects of this study were an instructional media expert, a subject matter expert, and ten eighth-grade students at SMP Negeri 2 Tondano. This research aims to develop a STEM-based science e-module on the human excretory system topic. The preparation activities until the product feasibility validation test were carried out from February to March 2022 at the Department of Science Education, Universitas Negeri Manado. On the other hand, a limited trial in the form of a small group student response trial was conducted in April 2022 at SMP Negeri 2 Tondano.

The data collection techniques that we use are interviews and questionnaires. Interviews are a data collection method in which an interviewer asks the respondents face-to-face, via telephone, or online (Moser & Korstjens, 2018). A questionnaire is a set of questions to gather data from respondents (Taherdoost, 2022). The instruments used in this study were interview sheets, product validation questionnaires, and product practicality questionnaires. The questionnaire was used to assess the product feasibility. The validators filled out the validation questionnaire by giving an assessment referring to the score criteria of 4 (strongly agree), 3 (agree), 2 (less agree), and 1 (disagree).

After receiving an assessment from the validator, the value obtained is analyzed. After the results of expert validation, the e-module was tested on a small group of 10 eighth-grade students at SMP Negeri 2 Tondano. Equation 1 below is used to obtain validation proportion scores and student response trials.

$$P = \frac{\sum x}{\sum x_i} \times 100\% \quad (1)$$

Information: P = percentage, $\sum x$ = number of validator scores, and $\sum x_I$ = total ideal scores.

After obtaining the proportion value, the next step is to interpret this value on the criteria for the level of validity and practicality, which can be seen in Table 1.

Table 1. Product Validity and Practicality Criteria (Arikunto, 2010)

Intervals (%)	Criteria	
80 - 100	Very valid (No need to revise)	Very practical
60–79	Valid (Requires minor revision)	Practical
40–59	Less valid (Requires major revisions)	Less practical
0 – 39	Invalid (Not suitable for use)	Not practical

Based on Table 1, the developed product is deemed fit for use if it obtains a minimum percentage of 60%.

Result and Discussion

This research successfully produced a STEM-based science e-module on the human excretory system topic that is suitable for use by junior high school students. The following are the results at each stage of the development carried out.

Planning and Learning Products

At this stage, planning is carried out by considering the learning objectives and determining the types of products to be developed. There are four learning objectives on the topic of the human excretory system: Students can explain the meaning of the human excretory system, students can explain the structure and function of the human excretory system, students can explain disorders of the human excretory system, and students can explain the correct lifestyle to maintain a healthy system excretion. Next, the researchers decided to develop a STEM-based science e-module on the human excretory system topic by utilizing the Flip PDF Corporate Edition application.

Exploratory Studies

We conduct preliminary research or initial observations in schools. We conduct observations and interviews with science teachers to obtain information about the current learning situation, STEM involvement,

and electronic teaching materials. The results of our interviews with science teachers at SMP Negeri 2 Tondano provide information that teachers use more lecture methods in learning, prioritize the use of printed books, make presentations using PowerPoint, have never used interactive media, and are not familiar with STEM learning. On the other hand, students generally can use computers and are accustomed to using smartphones. In addition, student mastery of the topic of the human excretory system is still standard.

Early Form Development

The subject matter in this e-module comes from various sources: printed books, research articles, and other electronic books. Then typed in the Microsoft Word application, then converted it into PDF format. The file is then imported into the Flip PDF Corporate Edition application to add the required video, audio, and images. After it is deemed complete, then the e-module is published on the flip builder website. E-modules that have been published are equipped with links to be accessed online. The appearance of e-modules in several electronic devices is shown in Figures 2, 3, and 4.

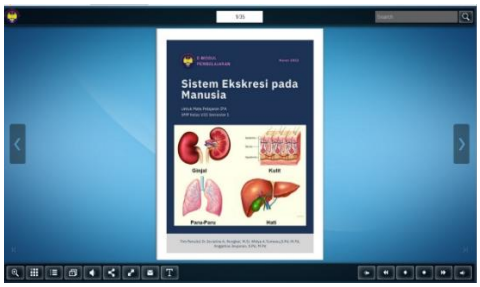

Figure 2. Display of the e-module on a computer/laptop

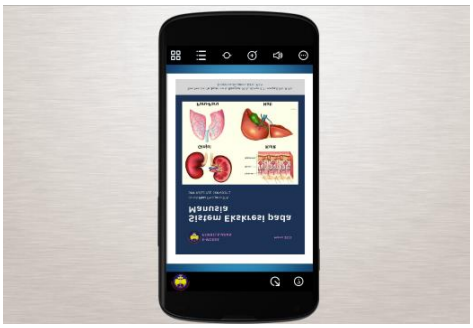

Figure 3. Display of the e-module on a smartphone

Figure 4. Display of the e-module on an electronic tablet

Data Collection and Analysis Instruments

The instruments used in data collection are questionnaires and tests. The questionnaires used by the researchers were subject matter expert questionnaires, learning media experts, and product practicality questionnaires through limited trials in small groups. Data were analyzed using the Microsoft Excel 2013 application to calculate the collected research data.

Validation Activity: Learning Media Expert

Based on the media expert's assessment, the total number of categories strongly agreed (SS) was 28, the category agreed (S) was 2, the category disagreed (TS), and the category strongly disagreed (STS) was none. The validation results by media experts are shown in Table 2.

Table 2. Media Expert Validation Results

Aspect	Percentage (%)	Category
Display screen design	100	Very valid
Ease of use	92.86	Very valid
Consistency	100	Very valid
Usefulness	100	Very valid
graphics	100	Very valid
Average	98.33	Very valid

Table 2 shows that the percentage obtained from the results of the media expert's assessment is 98.33%. This percentage is included in the very valid category (no need for revision). There are five aspects assessed by media experts: screen design appearance, ease of use, consistency, usability, and graphics. These results indicate that the developed e-module meets the criteria of good learning media. This research aligns with the results of Lestari et al. (2020), who reported that the e-module they developed scored 90.3%, including the very feasible category. Research by Hutomo et al. (2022) also showed the same results, where the e-module they developed received a score of 98.08% and was included in the very proper category by media experts.

Validation Activity: Learning Material Expert

Based on the assessment of material experts, the number of categories of material experts strongly agree (SS) 29, the category agrees (S) 1, the category disagrees (TS), and the category strongly disagrees (STS) does not exist. The validation results by media experts are shown in Table 3.

Table 3. Material Expert Validation Results

Aspect	Percentage	Category
Content eligibility	98.33	Very valid
Language Eligibility	100	Very valid
Presentation eligibility	100	Very valid
Average	99.17	Very valid

Table 3 shows that the percentage obtained from the results of the material expert's assessment is 99.17%. This percentage is included in the very valid category (no need for revision). There are three aspects assessed by material experts, namely content feasibility, language feasibility, and presentation feasibility. These results indicate that the developed e-module has a correct scientific concept. This research is in line with Kosasih et al. (2023), who reported that the validation of material experts on the e-modules they developed showed a value of 81.25%, including in the very valid category. In addition, research by Ravista et al. (2021) also showed the same results, where the evaluation by material experts of the developed e-module obtained a score of 85.30%, which is included in the very good category.

Validity is very important when choosing and using an instrument in research. Validity can be defined as the extent to which evidence and theory support the interpretation of test scores (Almanasreh et al., 2019). Validity is a measure that indicates the level of validity or validity of an instrument (Arikunto, 2014). Conversely, a less valid instrument means a low validity value. In addition, a teaching material is valid if it can show conditions that are in accordance with its content and construct.

Small Group Evaluation

This small group test data is part of a limited trial. We obtained the data by assessing 10 eighth-grade students at SMP Negeri 2 Tondano. The students gave varied responses with the category strongly agree (SS) 70%, the category agrees (S) 30%, there was no category disagree (TS), and the category strongly disagrees (STS). The results of trials limited to small groups are shown in Table 4.

Table 4. Limited Trial Results in Small Groups

Aspect	Percentage	Category
Clarity of content	94.75	Very valid
Language Clarity	91.67	Very valid
Usefulness	92.00	Very valid
Presentation	93.50	Very valid
Average	93.40	Very valid

Table 4 shows that the percentage obtained from the results of limited trials through small-group evaluations is 93.40%. These results indicate that the e-module we developed is included in the very practical category. Four aspects are assessed: content clarity, language clarity, usefulness, and presentation. Thus, the e-module we have developed is practical for junior high school students. Similar research by Sari & Andromeda (2023) reported that the e-module they developed was practical for students with an acquisition score of 91%, included in the very practical category.

Revision Based on Validation Results

After going through the stages of expert validation and student trials, the e-module product is revised or perfected. Suggestions from validators and revisions made are shown in Table 5.

Table 5. Suggestions and Revisions

Validators	Suggestion	Revision
Learning Media Expert	The human body image used on the cover page is still too general. It is better to use pictures of organs in the human excretory system to look more specific.	The image on the cover page has been replaced with a picture of the organs in the human excretory system.
Material Expert	The first practicum guide video does not yet cover STEM's "mathematics" component.	The first practicum guide video has been changed to include a "mathematics" component in STEM.
	The second practicum guide video does not cover STEM's "engineering" component.	The second practicum guide video has been changed to include STEM's "engineering" component.

The module we have developed is an electronic version of the printed module so that it can be read through various electronic devices. The e-module we have successfully developed can be accessed at the link https://online.flipbuilder.com/ptsqz/elwq/. This link can be shared via social media and accessed online via various electronic devices, such as smartphones, computers, tablets, notebooks, and laptops. Bröhl et al. (2018) stated that digital technology is an integral part of daily activities, with the most widely used electronic devices being desktop or laptop PCs, tablet PCs, and smartphones. It is the impact of fulfilling the needs of today's society which is always moving forward, causing the rapid development of information and communication technology and the widespread use of technological advances, such as laptops, tablets, and smartphones, which are connected through the internet networks and software (Castillo-Manzano et al., 2017). As a result, paradigms in education are shaped and can be seen through various types of mobile devices.

E-modules are one of the innovative digital-based teaching materials or learning media that can support 21st century skills in education (Prabasari et al., 2021). E-module is learning tools or tools that contain materials, methods, limitations, and evaluation methods designed systematically and attractively to achieve the expected competencies following the level of complexity electronically (Hakim et al., 2020). Pratiwi et al. (2021)

stated that e-modules are teaching materials that can be accessed via various gadgets, namely smartphones, tablets, and laptops. Meanwhile, according to Winaya et al. (2016), an electronic module or e-module displays information in a book format presented electronically using a hard disk, diskette, CD, or flash disk and can be read using a computer or an electronic book reader. Setianingrum et al. (2022) stated that using e-modules through electronic devices also supports digital literacy for students.

Conclusion

This research succeeded in developing one of the innovative learning media products in the form of STEM-based science e-modules on the human excretory systems topic for junior high school students that are feasible to use. It can be seen from the results of expert assessments of learning media, subject matter, and limited trials of 10 students to determine the product's practicality. The results of the validation of learning media experts show a value of 98.33% and are included in the very valid category (no need for revision). The subject matter expert validation results show a value of 99.17% and are included in the very valid category (no need for revision). In addition, the results of a limited trial in a small group show a value of 93.40% and are included in the very practical category. Thus, the STEM-based science e-module on the human excretory system topic is suitable for use by junior high school students.

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Author Contributions
Conceptualization, J.A.R. and A.J.; methodology, J.A.R. and A.J.; software, A.J.; validation, J.A.R. and B.R.W.; formal analysis, B.R.W.; investigation, J.A.R. and A.J.; resources, A.J.; data curation, B.R.W.; writing—original draft preparation, A.J.; writing—review and editing, B.R.W. and Z.W.M.W.; visualization, B.R.W.; supervision, J.A.R.; project administration, J.A.R.; funding acquisition, J.A.R. and Z.W.M.W. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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