

## Research Article

# Development of Android-Based Interactive Learning Media to Promote Green Chemistry Principles in Higher Education

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## ABSTRACT

This study aims to determine the feasibility of Android-based green chemistry learning media integrated with Smart App Creator, developed to improve students' cognitive learning outcomes, assess student readiness toward new learning modes, and analyze student responses to the developed media. The research employed a Research and Development (R&D) approach adapted from the Borg & Gall model combined with the 4-D procedural model, encompassing the stages of define, design, develop, and disseminate. The learning media product was developed in the form of an Android application focusing on green chemistry concepts and designed using the Smart App Creator software. The feasibility of the developed media was evaluated through expert validation and user response assessments. The results of the validation indicated that the media achieved a validity score of 84% and a quality score of 87%, both categorized as "very good." In addition, student responses toward the use of the learning media were highly positive, reaching 92%, which reflects a high level of acceptance and readiness to adopt technology-based learning. Furthermore, the implementation of the developed Android-based media demonstrated a significant influence on students' cognitive learning outcomes, with 72% of students achieving learning completeness. Overall, the findings indicate that the Android-based green chemistry learning media integrated with Smart App Creator is feasible, practical, and effective for supporting chemistry learning. This media offers a promising alternative for enhancing cognitive learning outcomes and facilitating the integration of digital technology into chemistry education.

**Keywords:** Android learning media; green chemistry; higher education; R&D

## 1. INTRODUCTION

Improving the quality of education in Indonesia can be developed through the implementation of educational reforms. Changes that occur in traditional learning towards learning that further enhance critical thinking are called educational reform (Redhana, 2010; Sugiyarto et al., 2018 and Sumiati et al., 2018). Many branches of knowledge must be studied to achieve academic goals. Education must align with the quality of educators and adequate facilities and infrastructure to realise education and create a quality generation through the paradigm shift in the direction of schooling towards technology. Based on Ministerial Regulation "Permendikbud 109 /2013" concerning the Implementation of Distance Education (Pendidikan Jarak Jauh/PJJ) in Higher Education, and "Permendikbud 119/2014" concerning Implementation of PJJ for Elementary and Secondary Education, PJJ aims to increase the expansion and equitable distribution of access and facilitate services ranging from basic education to secondary education, with open characteristics, independent learning, complete learning, using educational information and communication technology, and using other educational technologies.

By government recommendations through the Ministry of Education and Culture's policy of "Merdeka Belajar" and "Kampus Merdeka" inspired researchers to support the program through innovation of the PJJ mechanism by these policies, which is applied in the form of android and can be accessed by gadgets, be it PC, laptop, or mobile phone, as the current development of education has entered the realm of Education 4.0 fit for Industry 4.0. In this regard, all areas of life will lead to digitalisation, so that the digitalisation of education cannot be ignored anymore. Android learning media is an effective tool in developing students' skills in answering questions. Android learning media can be auditory, meaning learning must be through listening, speaking, achievement, argumentation, expressing opinions and responding. While intellectually means that learning must use the ability to think (mind-on), it must be by concentrating the mind and practising using it through reasoning, investigating, identifying, discovering, creating, constructing, solving problems and applying. Then, as media repetition means repetition, which means deepening, expanding, and stabilising, students are trained through giving assignments or tests.

The integration of Android learning media is expected to solve various challenges, namely overcoming the limitations of experiments in science learning, as well as increasing the cognitive aspect, where students can learn independently to solve problems and improve their logical thinking by utilising various innovations that were born in the era of the industrial

revolution. 4.0, such as the Internet of Things, artificial intelligence, big data, and robots, to improve the quality of human life (Sugiyarto, et al, 2018; Setiawaty, et al, 2020). Android-based Smart App Creator should significantly improve logical thinking skills and learning outcomes (Setiawaty et. al., 2022). This can also be interpreted as a human- and technology-centred learning concept. Studies conducted by Tokac et al. (2019) and Hung et al. (2014) found that the effects of video games on students have significantly more positive impacts than traditional instructional methods. They also studied the moderation effects of grade level, instrument type, game-based intervention length, country, publication type, and study year characteristics on learning achievement.

The concept of green chemistry in learning is an approach to designing chemical processes and products that are safer for the environment and human health. It aims to develop chemical processes and chemical products that are environmentally friendly and sustainable (Prabawati et al., 2015). Green chemistry has 12 principles that can be adapted to be applied in human attitudes and actions to save the environment. The principles of green chemistry can be adapted to be applied in human attitudes and actions to save the environment, which can be realised through green education (Mitarlis et al., 2016). Green chemistry learning is meaningful to reduce or eliminate hazardous chemicals and minimise waste and pollution resulting from chemical processes. Green Chemistry Learning aims to increase awareness and understanding of the environmental impacts of chemical processes, where students will learn about the importance of protecting the environment and human health, and understand how chemical processes can impact both—furthermore, equipping students with the knowledge and skills to design safer chemical processes and develop critical and innovative thinking skills in finding solutions to environmental problems. In this case, students will be invited to think creatively and innovatively in designing environmentally friendly solutions to environmental problems related to chemical processes, so that the integration of Android media in green chemistry learning is very appropriate for creating innovative green chemistry learning. Efforts that can be made so that students can understand the material and apply it to their daily lives include developing teaching materials in the form of worksheets, which are packaged in electronic form. Packaging worksheets in electronic form aims to make it easier for students to repeat learning. According to Mitarlis et al. (2015), it has high effectiveness in supporting the chemistry learning process. Meanwhile, according to Imanda et al. (2017), the use of e-worksheet has been proven effective in improving student learning outcomes in chemistry material with high effectiveness. Based on research Setiawaty et al., 2018 and Imanda et al., 2021, the use of worksheets in chemistry learning has a high effectiveness value and can improve students' abilities in learning.

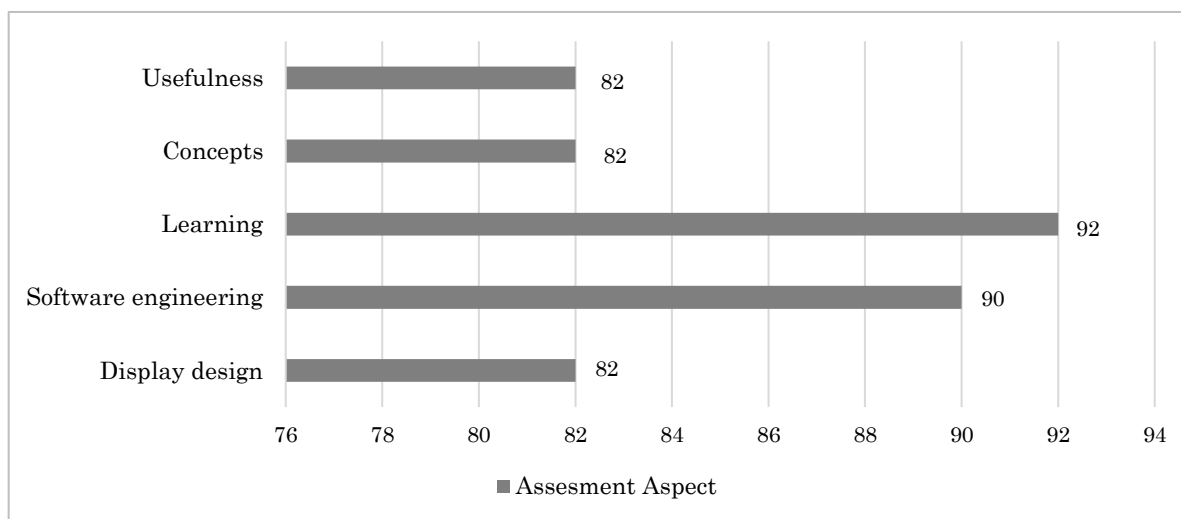
## 2. RESEARCH METHOD

The research and development procedure carried out is an adaptation of the research and development (R&D) research (Borg & Gall, 2007) and 4-D (Define, Design, Development, and Disseminate) procedures (Thiagarajan, et al., 1974), to develop Android learning media with Smart app creator software, and will be implemented in senior high schools in North Aceh Regency. The research procedures to be carried out are described: 1) Definition (Define): (a). Front and analysis, (b) learner analysis, (c) task analysis, (d) concept analysis, and (e) specifying instructional objectives; 2) Design: (a) constructing criterion-referenced test, (b) media selection, (c) format selection and (d) initial design; 3) Development: (a) expert appraisal, and (b) developmental testing; 4) Dissemination: (a) validation testing, (b) packaging and (c) diffusion and adoption. The subjects of this research were two chemistry teachers and 30 senior high school/equivalent students in the district of North Aceh, Indonesia. The instruments used in this study were validation sheets, media feasibility questionnaire sheets, and student response questionnaire sheets. Validation sheet data and questionnaire sheets are calculated using a Likert scale—the data obtained from the results of the validation and eligibility tests, and the response questionnaire.

## 3. RESULTS AND DISCUSSION

### 3.1 Development of Android Learning Media

The development of Android learning media refers to the cognitive learning outcomes demands of the Merdeka Curriculum, which aligns with the program, to increase the capability and quality of the ICT-integrated Learning Resource Centre by the Ministry of Education and Culture. At this stage, an initial analysis is carried out to see the needs of students and adjust to the needs of students and school conditions (front analysis). Furthermore, a learner analysis, task analysis, concept analysis and specifying instructional objectives was also carried out design android-based green chemistry learning media integrated Smart app creator software to match competencies and learning outcomes based on the Decree of the Minister of Education and Culture of the Republic of Indonesia (“958/P/2020”) concerning Learning Outcomes in Early Childhood Education, Basic Education, and Secondary Education. Next, media design is carried out. This activity is called the design stage, where the media is designed before development is carried out by planning a framework before developing the product, through the preparation of reference criteria tests, media selection, format selection, and initial design. After this stage, the process is completed and continued with the development stage. This development stage consists of expert assessments and development testing focusing on validating, reviewing, and evaluating the feasibility of designing Android learning media products. The following is the percentage of assessment results obtained from expert validators.



**Figure 1.** Diagram of validation results from the expert validator assessment

The Android learning media has been meticulously crafted using Smart App Creator software, focusing strongly on the content, learning outcomes, and feedback from educators and validators. Teachers have noted the necessity for more media content, particularly due to the limited green chemistry concepts available in the X class of the Merdeka curriculum. Moreover, research indicates that digital games can significantly enhance students' learning achievements in education, contributing to a better understanding of digital learning applications and practices (Setiawaty et al., 2022; Wang et al., 2022). The validity and quality of the developed learning media received assessment scores of 84% and 87%, categorizing them as "Very Good." Widoko (2014) noted that these validation scores fall within the very high category, affirming that the product is suitable for limited testing without requiring revisions.



**Figure 2.** (a), (b) Display of Android learning media

Android learning media plays a crucial role in chemistry education by allowing students to participate actively. It encourages participation through discussions and responses to questions, making the learning experience more meaningful and engaging. As a result, students develop greater curiosity about the subject matter. With Android learning media, students can focus better, grasp the content effectively, and develop an interest in the presented material. This aligns with the functions of Android learning media, which serve as a two-dimensional tool. The attention function captures students' focus, the affective function relates to the enjoyment students feel while learning, and the compensatory function provides context that helps them understand the reading material (Fitri, 2018). In addition to enhancing student engagement, using Android learning media in chemistry also facilitates teachers in conveying the material. It addresses space, material, and time limitations, as not all objects or events can be brought into the classroom. The advantages of using such media include: (1) overcoming limitations of space, time, and observation since not all objects can be brought into class; (2) providing a more concrete and realistic representation than verbal media; (3) serving as a learning resource suitable for all age groups; and (4) offering dimensional space where concepts can be presented in a two-dimensional format that is engaging to read (Setiawaty et al., 2023).

### 3.2 Students Learning Outcomes

Implementing Android learning media has the potential to significantly enhance students' cognitive learning outcomes, achieving green chemistry learning.

**Table 1.** Student' cognitive learning outcomes

Pretest		Posttest		<g>
Average value	Completeness (%)	Average value	Completeness (%)	
28.05	0	74.5	72	0.65

Based on the results obtained, the application of the developed media can also significantly influence students' cognitive learning outcomes with a 72% completeness. This is in addition to the primary objective of increasing students' cognitive learning in Android media. In addition to the primary aim of improving students' learning outcomes in chemistry learning. Furthermore, researchers have noted that digital games can achieve diversified Android learning goals that enhance students' learning motivation, reduce their anxiety, and indicate the improvement of flow experience, creative confidence, social constructs, and their understanding of knowledge concepts, and cultivate their problem-solving abilities (Hwang et al., 2012; Setiawaty et al., 2018; Gu et al., 2022; Kijima et al., 2021). This is in line with the results of research by Setiawaty et al. (2022), Harvey & Kamvounias (2008), and Imanda et al. (2022) that the application of good and interesting media and the effectiveness of the product can provide a positive impact on students' competencies and cognitive learning outcomes. Furthermore, learning media-based technology is effective in enriching the teaching and learning experience, improving spatial cognition abilities (Irwanto, et al., 2022), reducing cognitive load (Allagui, 2019), and making it easier for students to understand context-specific skills and knowledge (Sugiyarto, et al., 2019).

#### 4. CONCLUSION

This study aims to evaluate the feasibility of Android-based green chemistry learning media integrated with Smart App Creator, which was designed to improve students' cognitive learning outcomes, assess student readiness for renewed learning modes, and examine student responses to the developed media. The integration of digital technology in chemistry education is expected to support more engaging, flexible, and effective learning processes. To achieve these objectives, the study employed a Research and Development (R&D) approach adapted from the Borg and Gall model and the 4-D procedural model, covering the stages of defining, designing, developing, and disseminating the learning media. The learning product developed in this research is an Android application that presents green chemistry concepts in an interactive and user-friendly format. The application was created using Smart App Creator software to ensure accessibility and ease of use for students. The feasibility and quality of the learning media were evaluated through expert validation involving material, media, and language aspects. The validation results showed that the media achieved a validity score of 84% and a quality score of 87%, both categorized as "very good." In addition, student responses toward the developed media were highly positive, reaching 92%, indicating strong acceptance and readiness to adopt technology-based learning. Furthermore, the implementation of the Android-based green chemistry learning media demonstrated a positive and significant influence on students' cognitive learning outcomes, with 72% of students achieving learning completeness. These findings indicate that the developed media is feasible, practical, and effective for supporting green chemistry learning and promoting improved cognitive outcomes through technology-enhanced instruction.

#### RECOMMENDATIONS

The results of this research and study are expected to provide information, insight, and knowledge that will benefit readers and institutions.

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#### AUTHOR'S CONTRIBUTIONS

All authors participated in discussing the results and contributed to the final manuscript from the beginning, including design and analysis considerations, data collection, analysis performance, and paper writing.

#### CONFLICT OF INTEREST

The authors have no conflicting interests of any kind in the submission of this research paper.

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