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# DEVELOPMENT OF DIGITAL ASSESSMENT TOOLS USING WORDWALL AND PLICKERS FOR CHEMISTRY LEARNING IN SENIOR HIGH SCHOOL

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## ABSTRACT

This study addresses the need for interactive digital assessment tools in chemistry learning, where traditional evaluation often fails to engage students or provide immediate feedback. Wordwall and Plickers were selected as platforms because both are widely accessible and classroom-friendly, yet their effectiveness in formative evaluation has not been systematically compared. The purpose of this research was to develop and evaluate interactive assessments based on these two applications for high school chemistry. A Research and Development (R&D) approach was applied by combining the Borg & Gall and 4-D models. The process included four stages: (1) Define analyzing curriculum requirements and learner needs; (2) Design and construct interactive items and adapt them to Wordwall and Plickers; (3) Develop expert validation covering content accuracy, construct clarity, and usability, followed by revisions and limited trials; and (4) Disseminate large-scale implementation with 200 tenth-grade students from public high schools in Aceh Province. Instruments consisted of expert validation sheets, student response questionnaires (attractiveness, ease of use, and learning benefit), and pretest–posttest assessments. The results showed high validity (CVR = 0.90), positive student responses, and significant learning gains for both platforms (N-gain = 0.70 for Wordwall, 0.64 for Plickers). No significant difference was found between them ($p = 0.252$), indicating that both tools are valid, practical, and effective for formative assessment in chemistry learning.

**Keywords:** digital assessment, wordwall, plickers, chemistry education, formative evaluation

## INTRODUCTION

In the landscape of 21st-century education, technological advancement has become a key driver of pedagogical innovation. Digital tools not only facilitate access to knowledge but also

offer creative and efficient methods to assess students' understanding and skills. According to Li (2023), technology is a tool created to ease human work so that it is more efficient and faster. The development of 21st century technology in the field of education can be utilized to support the learning process where 21st-century teachers are required to be able to master skills related to technology (Asthana et al., 2022; Chai & Kong, 2017; Tondeur et al., 2017). As mandated by the Minister of National Education Regulation No. 16 of 2017, one of the core competencies for teachers is the ability to incorporate information and communication technology (ICT) into teaching and learning activities (Esteve-Mon et al., 2020; Scott, 2017; Tyan et al., 2020).

According to the International Society for Technology in Education (ISTE, 2008), 21st-century educators are expected to facilitate learning and creativity, design digital-age assessments, model digital practice, promote digital citizenship, and engage in professional growth and leadership. Among these, the ability to design varied formative and summative assessment tools that leverage technology is particularly crucial in supporting student-centered learning.

In 2021, Indonesia's education policy shifted from the National Exam (UN) to the National Assessment (AN), marking a fundamental change in how student competencies are measured (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2020). Unlike the UN, the AN emphasizes literacy, numeracy, and character competencies through diverse question formats, including multiple-choice, short answers, matching, and case-based reasoning (OECD, 2023; Twist, 2021). To succeed, students must be familiar with adaptive and technology-based assessments that mirror these formats. Therefore, not only does the use of digital assessment tools align with policy directions, but it also plays a crucial role in enhancing student preparedness for national evaluations.

Digital tools also offer significant advantages for students: they provide real-time feedback, allow for repeated practice in engaging formats, and can accommodate diverse learning needs, such as differentiated pacing and interactive question types (Napal et al., 2020; Zhang & Yu, 2022). For example, game-based quizzes can boost motivation, while immediate feedback from interactive tools helps students identify misconceptions quickly. These features make digital assessment particularly relevant for supporting student-centered and inclusive learning. A preliminary survey conducted among high school teachers in Langsa City, Aceh, revealed that around 75% of respondents lacked confidence in using digital tools for assessment purposes in their classrooms (Ihsan et al., 2022).

To address these challenges, the use of digital assessment technology needs to be encouraged and supported. Digital tools offer several advantages, including real-time feedback, increased efficiency, and the ability to accommodate diverse student needs. Innovations in assessment instruments are therefore essential not only to overcome existing obstacles but also to enhance the quality and inclusivity of student learning experiences.

This study selected Wordwall and Plickers due to their complementary strengths. Wordwall enables customizable, game-based quizzes that support multiple question formats aligned with AN, while Plickers allows low-resource classrooms to conduct real-time formative assessments without requiring student devices (Kent, 2019; Marensi et al., 2023). Previous studies have highlighted their benefits in enhancing engagement and assessment efficiency (Gandasari & Pramudiani, 2021), but research on their application in chemistry learning at the high school level remains limited. Moreover, there has been minimal focus on addressing weaknesses such as the limited item variety in Wordwall and the lack of detailed feedback in Plickers.

By addressing these gaps, this research aims to develop and validate digital assessment tools based on Wordwall and Plickers for high school chemistry. The study contributes both theoretically and practically by aligning tool development with national policy changes, enhancing students' readiness for AN, and offering practical models for integrating digital assessment into science education.

## METHODS

### Research Approach

This study employed a Research and Development (R&D) design that integrates Borg & Gall's ten-step model with the 4-D model (Define, Design, Develop, Disseminate). The integration allowed for a more systematic and iterative process of product development, validation, and implementation. Borg & Gall's framework provided the broader sequence of R&D, while the 4-D model was embedded at the product creation stages to ensure the instrument's feasibility and usability. Figure 1 (research flow) illustrates how both models were combined, including the activities, techniques, and outputs at each stage.

Define (Borg & Gall steps 1–2): Curriculum analysis, needs assessment, and preliminary survey of teachers and students regarding digital assessment readiness. Design (steps 3–4): Drafting quiz prototypes using Wordwall and Plickers, aligning items with the 10th-grade chemistry curriculum on *electrolyte and non-electrolyte solutions*. Develop (steps 5–7):

Validation by experts, small-scale testing, revisions based on feedback, and refinement of quiz interfaces. Disseminate (steps 8–10): Classroom implementation across selected schools, evaluation of effectiveness, and dissemination of findings.

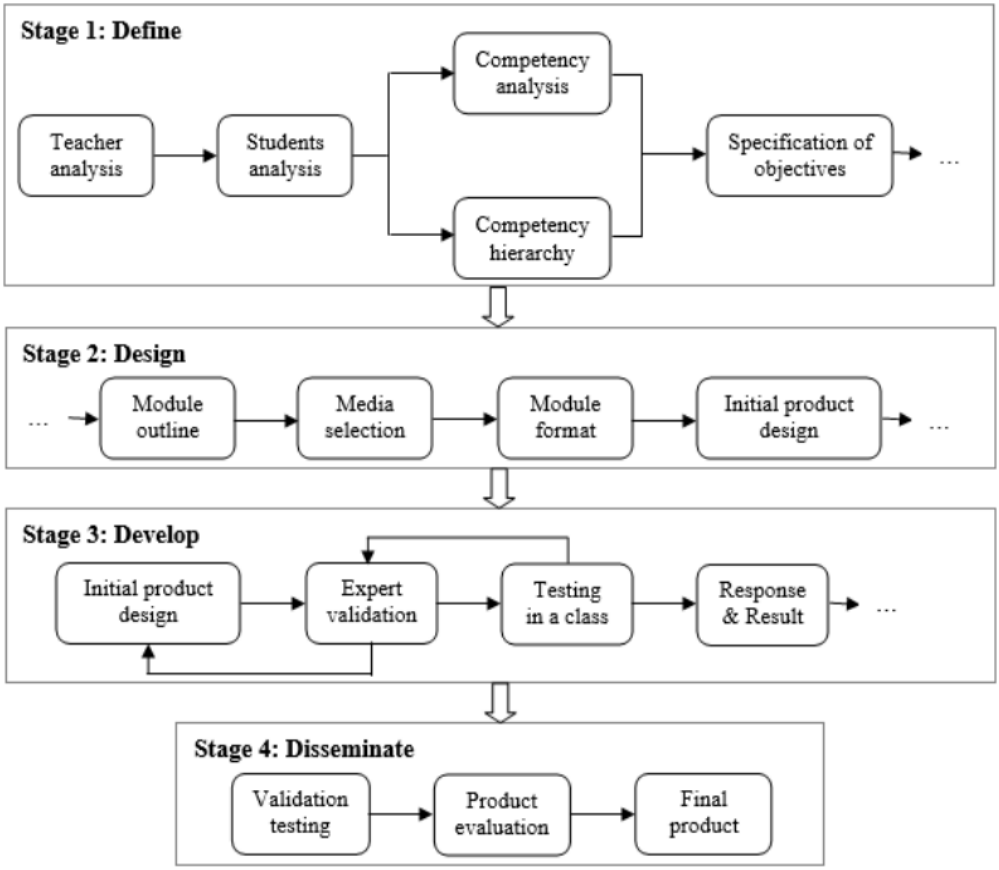


**Figure 1**. The Four-D model (Adapted from Puspitaningayu, et al. (2018))

**Participants and Research Context**

The participants consisted of 200 tenth-grade students from public high schools in Aceh Province, selected purposively to represent different accreditation levels: 40% from A-accredited schools, 35% from B-accredited schools, and 25% from C-accredited schools. Most students were familiar with basic ICT applications (e.g., Google Classroom, PowerPoint), but approximately 70% had never used Wordwall or Plickers in classroom assessment. Schools were equipped with adequate ICT infrastructure (projectors, Wi-Fi), although resource gaps existed in C-accredited schools.

**Instruments**

Three types of instruments were employed in this study: expert validation sheets, pretest–posttest assessments, and a student response questionnaire. First, the expert validation sheets

were designed to evaluate both the media and content aspects of the developed digital assessments. Media validation focused on layout design, accessibility, navigation, interactivity, and technical functionality, while content validation emphasized the accuracy of chemistry concepts, clarity of question items, appropriateness of scientific language, and alignment with learning objectives. Validation was conducted by six experts, comprising three specialists in chemistry education, two in educational technology, and one in applied linguistics. The experts were selected based on their academic qualifications (minimum of a master's degree) and prior publications related to educational technology or science education. The validation process was carried out online using Google Forms, and the results were quantified using the Content Validity Ratio (CVR), which provided evidence of high content validity.

Second, the pretest and posttest instruments were developed to measure student learning outcomes. These consisted of 25 multiple-choice items covering the topic of electrolyte and non-electrolyte solutions, including concepts of properties, ionization, and conductivity experiments. In order to reflect the characteristics of the Indonesian National Assessment (AN), the items were structured in various formats, such as standard multiple-choice, complex multiple-choice, and case-based problem-solving. Item reliability was examined through Cronbach's alpha, with coefficients above 0.70 indicating satisfactory internal consistency.

Finally, a student response questionnaire was employed to capture perceptions of the developed tools. The instrument used a 5-point Likert scale and measured four dimensions: usability, engagement, clarity of content, and perceived effectiveness. It consisted of 20 items, which were reviewed and validated by two educational psychologists to ensure clarity and construct validity.

**Implementation and Data Collection**

The digital assessment tools (Wordwall and Plickers) were implemented during chemistry lessons across the participating schools. Each session lasted 90 minutes, beginning with a pretest, continuing with teaching activities supported by the tools, and ending with a posttest. Student responses and feedback were collected immediately after classroom sessions.

**Data Analysis**

The data analysis in this study consisted of three main stages: validation analysis, student response analysis, and learning outcome analysis. For the validation data, the Content Validity Ratio (CVR) was applied to quantify expert judgments on the developed instruments. A CVR score of 0.75 or higher was considered acceptable for confirming content validity. In addition

to quantitative scoring, qualitative feedback provided by the validators was carefully reviewed and integrated into subsequent revisions, particularly in improving item clarity, visual presentation, and response navigation.

The student response data were analyzed using descriptive statistics. Mean scores and percentages were calculated for each dimension of the questionnaire: usability, engagement, clarity of content, and perceived effectiveness. Student responses were categorized as *positive* if at least 70% of the participants selected "agree" or "strongly agree" on the Likert scale. This threshold was employed to ensure that the instruments were not only valid but also perceived as practical and engaging from the learners' perspective.

For the learning outcomes, student performance on the pretest and posttest was examined using the normalized gain (N-gain) formula proposed by Hake (1998). The N-gain values were classified into three categories: high ($\geq 0.70$), moderate (0.30–0.69), and low ($< 0.30$). To determine the statistical significance of learning improvements, paired-sample t-tests were conducted for each application (Wordwall and Plickers). Furthermore, independent-sample t-tests were employed to compare the relative effectiveness of the two applications. Effect sizes were calculated using Cohen's *d* to measure the magnitude of differences observed. A significance level of $p < 0.05$ was set as the threshold for all statistical tests.

## RESULTS AND DISCUSSION

### Development and Design of Digital Assessment Tools

The development of the Wordwall and Plickers digital-based assessment tools was carried out through a combination of the Borg & Gall and 4-D development models. The process began with a comprehensive needs analysis involving structured interviews and questionnaires with chemistry teachers. Three main aspects emerged as priorities: the need for digital assessments in numerically oriented materials (e.g., electrolyte solutions), the necessity of aligning assessments with the independent curriculum, and the limited mastery of existing digital tools among teachers. The data results of the needs analysis are as follows in Table 1.

**Table 1.** Chemistry Teacher Interview Results

| Indicator | Summary of interview results |
|---|---|
| Material analysis | Teacher A: A digital assessment on materials related to numerical concepts such as electrolyte and electrolyte solutions is needed for teachers.<br><br>Teacher B: A digital assessment is one of the latest innovations, and materials related to mathematical concepts are needed. |

| Indicator | Summary of interview results |
|---|---|
| | Teacher C: The concepts of acid-base and electrolyte and non-electrolyte solutions are often taught in class through various innovations, and this is suitable if applied through digital concepts. |
| Curriculum analysis | Teacher A: A literacy and numeracy-based Merdeka curriculum is urgently needed. |
| | Teacher B: Many teachers still do not understand the concept of the Merdeka curriculum. |
| | Teacher C: The Merdeka curriculum is still something new and needs to be studied more deeply. |
| Media analysis | Teacher A: Digital-based learning media has been introduced since Covid, and only a few applications are mastered. |
| | Teacher B: Digital learning media is needed, especially in the introduction of digital-based assessments. |
| | Teacher C: Computer-based media needs to be developed further. |

The design of the applications began with the creation of Wordwall and Plickers accounts, followed by the development of quiz content on chemistry topics for Grade X. Wordwall quizzes were shared with students via URL links and accessed using laptops or smartphones. Plickers quizzes used printed QR cards, scanned by the teacher's device to collect student responses in real time.

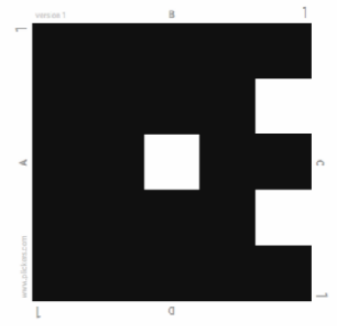

**Figure 2**. Sample Plickers Cards

These platforms were chosen for their accessibility, simplicity, and compatibility with various learning environments. Figure 2 above describes the simple Plickers cards. Then, Figure 3 describes how the class information is arranged at the beginning stage.

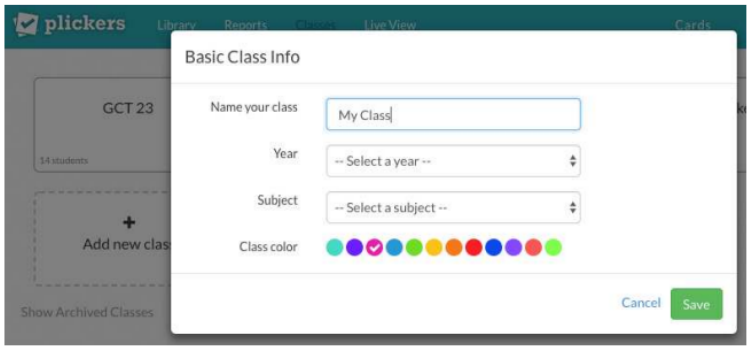


**Figure 3**. Adding a Class on The Website

During the Develop stage, the prototypes were uploaded, internally tested, and revised iteratively. Validation by experts ensured the feasibility of media design and the accuracy of content. The Disseminate stage involved implementation in public high schools across Aceh Province, followed by evaluation of student responses and learning outcomes.

**Feasibility and Validation**

Expert validation was conducted to assess the feasibility of the applications. Media experts evaluated three dimensions: appearance, accessibility, and programming quality. Table 2 shows the results of validation before and after revision.

**Table 2.** Media Expert Validation Results (CVR)

| Aspects | CVR (Before) | CVR (After) |
|---|---|---|
| Presentation and Interface Design | 0.6 | 0.9 |
| Application Components (videos/images) | 0.6 | 0.9 |
| Technological Feasibility | 0.6 | 0.9 |
| Average CVR | 0.6 | 0.9 |
| Description | Invalid | Valid |

Material experts assessed content accuracy, clarity, and language (Table 3). After revision, substantial improvements were made to ensure alignment with curriculum indicators and enhance interface usability.

**Table 3.** Material Expert Validation Results (CVR)

| Aspects | CVR Before | CVR After |
|---|---|---|
| Content Accuracy | 0.6 | 0.9 |
| Presentation Quality | 0.6 | 0.8 |
| Language Use | 0.6 | 0.8 |
| Average CVR | 0.6 | 0.85 |
| Description | Invalid | Valid |

Before being used in learning, digital media is first assessed for suitability by experts, both in terms of design and content. Experts evaluate various important aspects, such as visual appearance, ease of access, and suitability of the technology used, as well as the accuracy of the content, delivery methods, and language usage. To assess the extent to which each part is considered suitable by experts, a quantitative approach known as Content Validity Ratio (CVR) is used, as introduced by Lawshe (Lawshe, 1975). In Indonesia itself, such validation approaches are widely recommended by experts such as Mardapi and Arikunto, who both emphasize that learning instruments must undergo a feasibility test first to ensure they align with existing educational needs and contexts.

**Student Response**

To assess user engagement, a media attractiveness questionnaire was administered to 45 students using a 4-point Likert scale. Results are shown in Table 4. On average, 87.5% of students categorized the applications as "very interesting," suggesting that the digital tools successfully enhanced engagement and accessibility.

**Table 4.** Student Response to Application Attractiveness

| Application | Media Attractiveness | Accessibility | Material Presentation | Total Score | Attractiveness (%) |
|---|---|---|---|---|---|
| Wordwall | 3 | 4 | 3 | 10 | 83 |
| Plickers | 4 | 3 | 4 | 11 | 92 |
| Average | - | - | - | - | 87.5 |

**Learning Outcomes**

Pretests and posttests were administered to 200 students across high schools with varying accreditation levels (A = 45%, B = 35%, C = 20%). Normality tests (Kolmogorov–Smirnov and Shapiro–Wilk) confirmed that the data were normally distributed (Sig. > 0.05). The N-gain results are presented in Figure 4. In Figure 4, the results of the data on the increase in students' final scores on the Wordwall and Plickers e-assessment applications obtained a total N-gain value for the Wordwall application of 0.7 with a high category and Plickers of 0.64 with a medium category. Furthermore, the effectiveness of the use of Wordwall and Plickers e-assessment applications obtained an effect size value of which means very effective.

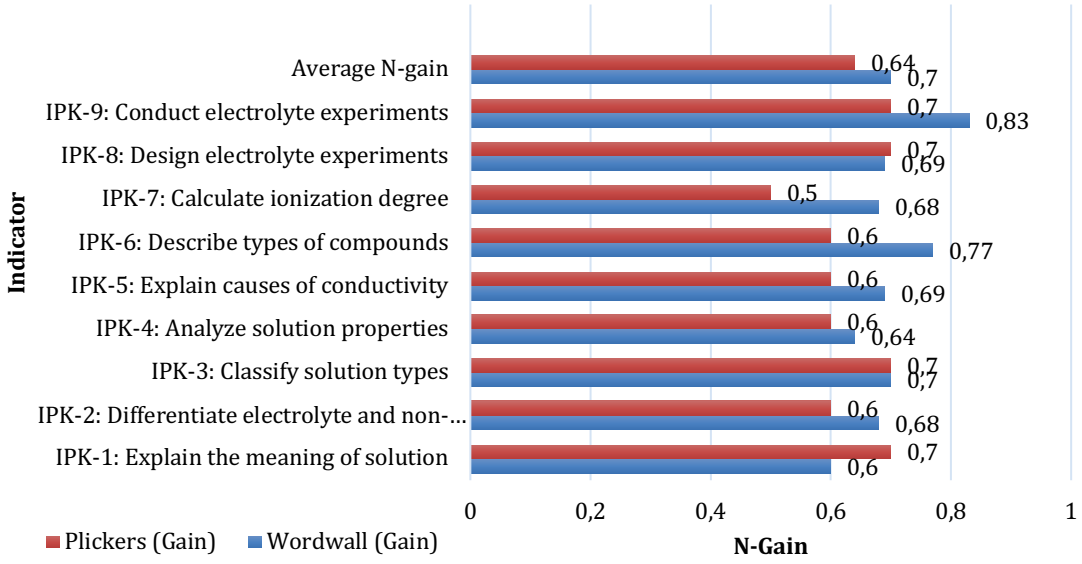


**Figure 4.** Pre-Test and Post-Test Results and N-Gain Scores

**Effectiveness and Comparison with Previous Studies**

The results of the paired sample statistics analysis showed an increase in the average score from the pretest (M = 4.94, SD = 1.39) to the posttest (M = 7.73, SD = 1.19) in 200 students (Table 5) who participated in the learning intervention using the Wordwall and Plickers applications.

**Table 5.** Paired Samples Statistics of Pretest and Posttest Scores (N = 200)

| Variable | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Pretest | 4.9361 | 200 | 1.38849 | 0.09818 |
| Posttest | 7.7251 | 200 | 1.19052 | 0.08418 |

Before conducting further parametric statistical tests, normality tests were performed on the pretest and posttest data to ensure that the data analyzed met the assumptions of normal distribution. These normality tests are important because they are one of the requirements for using parametric tests such as the *paired sample t-test*. In this study, normality tests were conducted using two approaches, namely the Kolmogorov–Smirnov and Shapiro–Wilk tests, both of which are used to detect the suitability of data for normal distribution (Table 6).

**Table 6.** Results of Normality Test for Pretest and Posttest Scores

| Instrument | Type of Test | Statistic | df | Sig. | Interpretation |
|---|---|---|---|---|---|
| Pretest Plickers | Kolmogorov-Smirnov | 0.073 | 100 | 0.200* | Normal |
| | Shapiro-Wilk | 0.978 | 100 | 0.096 | Normal |
| Posttest Plickers | Kolmogorov-Smirnov | 0.075 | 100 | 0.181 | Normal |
| | Shapiro-Wilk | 0.978 | 100 | 0.087 | Normal |
| Pretest Wordwall | Kolmogorov-Smirnov | 0.052 | 100 | 0.200* | Normal |
| | Shapiro-Wilk | 0.990 | 100 | 0.656 | Normal |
| Posttest Wordwall | Kolmogorov-Smirnov | 0.074 | 100 | 0.194 | Normal |
| | Shapiro-Wilk | 0.984 | 100 | 0.262 | Normal |

The results of normality tests using the Kolmogorov–Smirnov and Shapiro–Wilk methods indicate that all pretest and posttest data on both platforms, Wordwall and Plickers, have significance values above 0.05. This indicates that the data are normally distributed. Therefore, further data analysis can be performed using parametric statistical tests, such as the *paired sample t-test* or *ANOVA* (Table 7). These results also reinforce the reliability of the instrument in measuring changes in participants' skills across each indicator.

**Table 7.** Results of Paired Samples t-Test for Pretest and Posttest Scores Using Plickers and Wordwall Instruments

| Instrument | Mean Diff. | Std. Dev. | Std. Error Mean | 95% CI of the Difference (Lower) | 95% CI of the Difference (Upper) | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| Plickers | -2.80430 | 0.89336 | 0.08934 | -2.98156 | -2.62704 | -31.391 | 99 | 0.000 |
| Wordwall | -2.77380 | 0.98542 | 0.09854 | -2.96933 | -2.57827 | -28.148 | 99 | 0.000 |

The results of the paired sample t-test showed that there was a significant difference between the pretest and posttest scores on both the Plickers and Wordwall instruments. On the Plickers instrument, the mean difference was -2.80 ($t = -31.391$, $p < 0.001$), while on Wordwall it was -2.77 ($t = -28.148$, $p < 0.001$). A p-value less than 0.05 indicates that the implementation of technology-based instruments significantly improved students' learning outcomes. These results reinforce the effectiveness of digital assessment as a formative evaluation tool in interactive science learning (Nguyen et al., 2020; Akgun & Topal, 2021).

After conducting a paired sample t-test analysis that showed a significant increase from the pretest to the posttest in each group, the next step was to evaluate the difference in the average increase (N-Gain) between the two different groups, namely the group that used the

Wordwall and Plickers instruments. For this purpose, an independent sample t-test was conducted to determine whether there was a significant difference between the two independent groups.

**Table 8.** Results of Independent Samples t-Test on N-Gain Scores between Wordwall and Plickers

| Levene's Test for Equality of Variances | | t-Test for Equality of Means | | | | |
|---|---|---|---|---|---|---|
| F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval Lower Bound |
| 0.073 | 0.787 | -1.149 | 198 | 0.252 | -0.02900 | -0.07879 |

The results show that the variance between the Wordwall and Plickers groups is homogeneous (Levene's Sig. = 0.787 > 0.05), and there is no statistically significant difference in N-Gain between the two groups (t = -1.149, p = 0.252 > 0.05). The 95% confidence interval also includes zero, indicating similar effectiveness between the two assessment tools. This means that both digital evaluation media have comparable effectiveness in improving student learning outcomes. This finding is in line with research by O'Dwyer et al. (2015) and Lin et al. (2020), which states that various forms of interactive digital assessment can provide equivalent learning improvement results if designed with similar pedagogical principles.

Furthermore, the calculation of the effect size (Cohen's d = 2.16) suggests a very large effect, demonstrating that the observed improvement is not only statistically significant but also practically meaningful. According to Cohen (1988), an effect size above 0.8 is considered large; thus, a value exceeding 2.0 reflects a very strong educational intervention impact.

These findings align with previous studies that have shown the potential of interactive digital platforms in enhancing student engagement and achievement. For instance, Gandasari and Pramudiani (2021) found that Wordwall significantly increased student motivation and participation due to its gamified quiz structure, which supports instant feedback and visual reinforcement. Similarly, Gurisik and Demirkan (2020) reported that the use of Plickers in classroom assessments increased student attention and helped teachers quickly identify misconceptions, improving the overall quality of formative evaluation.

In addition, research by Nafi'ah et al. (2022) emphasized that digital tools, particularly those offering customizable and adaptive formats, contribute to more inclusive learning

environments and better alignment with 21st-century skills. The integration of such tools into the assessment process aligns with the growing demand for technology-supported learning, particularly within the framework of the Indonesian independent curriculum (*Kurikulum Merdeka*), which emphasizes higher-order thinking skills, digital literacy, and active student participation.

Taken together, these findings not only support the feasibility and effectiveness of Wordwall and Plickers in science education but also affirm their relevance as instructional innovations in post-pandemic, technology-integrated classrooms. The results of this study provide empirical evidence that digital assessment applications can be powerful instruments for improving learning outcomes and fostering more dynamic, student-centered learning environments.

## CONCLUSION

The systematic development of Wordwall and Plickers applications has demonstrated their validity, practicality, and effectiveness as interactive digital assessment tools in high school chemistry learning. The process began with a needs analysis that identified gaps in teacher readiness and student engagement, followed by the design of prototype assessments aligned with the independent curriculum and AN-type question formats. Expert validation confirmed the accuracy, clarity, and feasibility of the instruments, with high content and media validity indices (CVR $\geq$ 0.85). Subsequent classroom implementation involving 200 students revealed positive usability responses ($\geq$ 87.5% categorized as very interesting) and significant learning gains, with N-gain values of 0.70 (high) for Wordwall and 0.64 (moderate) for Plickers. Statistical analysis further supported these findings, showing highly significant differences between pre- and post-test scores ($p < 0.001$) and very large effect sizes (Cohen's $d > 2.0$).

These outcomes suggest that both applications provide feasible and scalable strategies for enhancing formative assessment in technology-supported learning environments. For chemistry educators, Wordwall and Plickers offer practical solutions to foster engagement, provide immediate feedback, and strengthen the implementation of inquiry-based and student-centered approaches as emphasized in the independent curriculum. Nonetheless, the study's regional focus and limited subject coverage highlight the need for broader investigations across diverse educational settings, disciplines, and ICT infrastructures. Future research should also examine long-term impacts and the scalability of these tools in supporting national assessment reforms.

By bridging gaps in digital assessment readiness and demonstrating measurable learning improvements, this study reinforces the potential of interactive platforms like Wordwall and Plickers to modernize assessment practices and contribute to more inclusive and effective science education.

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