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Innovative Pedagogical Approaches to the Periodic Table for Freshman Chemistry Student at the State University of Padang

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Abstract: This study developed innovative approaches to chemistry education for first-year students at the State University of Padang in the era of Industry 4.0. The research utilized the Plomp development model to formulate a method based on the Flipped Classroom paradigm with a Guided Inquiry Syntax. The resulting content was validated by five Chemistry lecturers at UNP, indicating its innovative and pertinent material depth. The content's practicality achieved a value of 90%, suggesting its ease of application and relevance for students. The systematic presentation enhances students' understanding of the Periodic System. This research offers valid and practical solutions to challenges in chemistry education, using creative content as an innovative strategy to provide a teaching tool that enhances students' understanding of complex concepts. The study's practicality stage demonstrates that the developed content is easy to apply and relevant for students, making it a valuable addition to chemistry education.

Keywords: Creative Content; Plomp Development Model; Flipped Classroom; Guided Inquiry Syntax; Merdeka Curriculum.

Introduction

This study seeks to improve first-year Chemistry students' comprehension of the periodic table by leveraging digital literacy and creative content on the Discord social media platform. The research addresses the challenges encountered in implementing the Merdeka Curriculum and advancing Industry 4.0.

This study is inspired by the struggles of first-year Chemistry students at Universitas Negeri Padang with the periodic table. The complicated concepts and formulas related to the periodic system often make it challenget for students to fully understand the subject. Also, the benefits of digital literacy and social media in Chemistry education have not been fully explored.

The research methodology employed encompasses a guided inquiry approach and a flipped classroom model. The guided inquiry technique is used to enable students to exercise their creativity in learning the material through inventive content about the periodic system (Syafei & Mawardi, 2022). Simultaneously, the flipped classroom model is implemented to promote autonomous learning via pre-recorded instructional videos. Utilizing the Discord social media platform, students are afforded opportunities to pose questions and engage in discussions with instructors and peers regarding the material they have studied.

The anticipated outcome of this investigation includes enhancing students' comprehension and abilities in determining the positions of elements within the periodic table. Additionally, the research aims to develop a valid and practical learning model that leverages digital literacy and social media for facilitating Chemistry education(Fosu et al., 2019). The study also seeks to produce a scholarly article suitable for publication in a reputable journal. Furthermore, it is expected to offer practical benefits for teaching Chemistry, particularly regarding the periodic system.

In this investigation, the proposed Technology Readiness Level (TRL) is Level 4, which involves employing technology to promote interactive and collaborative learning experiences(Dotimineli &

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Mawardi, 2021). In this case, the Discord social media platform and student-generated content can foster a more engaging and cooperative learning environment.

Figure 1. Flipped classroom Guided Inquiry Syntax integrated with Discord (Ismail & Mawardi, 2021)

To accomplish the research objectives, the investigator will utilize the Plomp research model, comprising four stages: preparation, realization, evaluation, and revision (Aumi & Mawardi, 2021). During the preparation phase, the researcher will develop learning materials, instructional videos, and a guided inquiry module(Nasution & Nandiyanto, 2021). The realization phase involves implementing learning through the Discord social media platform (Ismail & Mawardi, 2021). The evaluation phase will measure the development using questionnaires and comprehension tests. Finally, the revision phase will focus on refining and improving the devised learning model to ensure its validity and practicality.

This research conducted at Universitas Negeri Padang. Within the university's Merdeka curriculum, students are encouraged to cultivate creativity and digital literacy as vital competencies for the Industry 4.0 era.

Method

This investigation adopts an Educational Design Research (EDR) approach, a research methodology focused on devising solutions for intricate issues that emerge in educational practices where precise resolutions or explicit guidelines may be absent (Kardena & Mawardi, 2021; Plomp & Nieveen, 2007))The research and development method is employed to create a specific product and evaluate its practicality and validity. The development model implemented in this study is the Plomp model, established by Tjeerd Plomp (Plomp & Nieveen, 2007), which encompasses three primary phases: 1) Initial research phase; 2) Concept development phase (prototyping stage); and 3) Assessment and evaluation phase.

During the preliminary investigation phase, activities include context analysis, literature review, and concept development. In the prototyping stage, the focus is on designing and evaluating a learning system to determine its validity(Osokoya & R., 2016). The testing and evaluation phase involves conducting a practicality assessment (Syafei & Mawardi, 2022).

The initial steps of the research culminated in the development of a basic framework, achieved through needs analysis, context analysis, and literature review. This framework addresses current challenges in university-level chemistry education and proposes potential solutions.

In the first stage of **product development**, a teaching method is devised that incorporates the "Creative Content" approach combined with "Flipped Classroom Guided Inquiry Learning" via the social media platform "Discord." This preliminary version of the approach is referred to as "prototype 1 (Utami et al., 2019)"During the **self-evaluation stage**, researchers examined the products they developed, utilizing a feedback form (self-evaluation questionnaire) to guide their assessment. Based on the feedback received, modifications were made, resulting in the creation of "prototype 2."

The third stage of the product development involved a **comprehensive evaluation by experts**. The content was assessed by five chemistry teachers, while another group of five experts, including media professionals, reviewed the platform's appropriateness and functionality. The team made necessary adjustments based on their suggestions (Yuliana et al., 2020).

The next step was to conduct **one-to-one evaluations with actual users**, which involved three chemistry students from FMIPA UNP's 2023 batch. The students were selected to represent a range of academic abilities, including high, medium, and low. Each student used the product and provided their feedback and suggestions. The team used this feedback to develop "prototype 3." (Anjelina & Mawardi, 2021)

In the final stage, the team conducted **small group** testing with nine students from FMIPA UNP's 2021 batch. The students were selected based on their first-semester chemistry grades to represent a range of academic abilities. They engaged with the product during a learning cycle, and their feedback was gathered. After considering their insights, the team refined the product, resulting in the final version, "prototype 4." (Aumi & Mawardi, 2021). This rigorous testing process ensured that the product was thoroughly evaluated and refined to meet the needs of its users.

Information collected through observations and interviews is examined to derive conclusions. Following this, the input from expert validators is evaluated using the Aiken's V formula to establish the product's validity, as demonstrated in equation (1).

$$V = \frac{\sum s}{n\,(c-1)} \quad (1)$$

Information

- S: the score set by the validator minus the lowest score in the category used (s = r-Io), with the score category chosen by the validator and Io being the lowest score in the suspension category.
- N: Total number of validators
- C: Number of categories selected by the validator (Ismail & Mawardi, 2021).

For the data from the small group phase, which consists of student responses, the practicality of the product is gauged using equation (2).

$$P = \frac{f}{N} X100 \quad (2)$$

Information
P: Practicality Value.
F: Score
N: Maximum Score (Rao et al., 2016)

Result and Discussion

The primary aim of this research was to develop an inventive and efficacious educational instrument for first-year chemistry students at the State University of Padang, emphasizing the intricacies of the Periodic System. The Plomp development model functioned as the fundamental framework for this investigation, assisting in the creation of a curriculum anchored in the Flipped Classroom paradigm and enriched with Guided Inquiry Syntax.

The principal output, the innovative content, underwent thorough validation procedures. Five seasoned Chemistry lecturers at UNP assessed the material, yielding an impressive construct validity rate of 0.81 and a content component rate of 0.80. These values, considerably surpassing the benchmark for educational content validation, confirmed the scholarly depth and pertinence of the devised material. It is essential to highlight that attaining such scores signifies that the content not only conforms to academic standards but also aligns with the contemporary educational landscape, a crucial element given the evolving nature of the Merdeka Curriculum and the requirements of Industry 4.0.

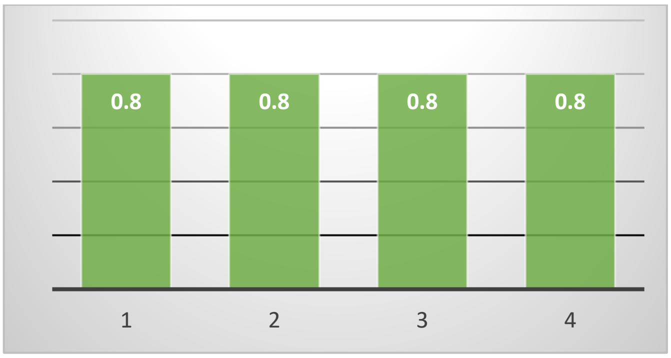

Figure 2. Chart of Content Validation

The research further evaluated the practicality of the developed content. Initial data indicates a value of 90%, signifying the ease with which this content can be incorporated into existing curricula and its potential for efficient dissemination among the target audience. It is crucial to consider this finding in the context of the Flipped Classroom approach. The core of this approach involves shifting from traditional teaching methods to more interactive, learner-centered ones. The high practicality score may be attributed to this, emphasizing students' preference for engaging, interactive content over conventional instructional techniques(Rohmah et al., 2019).

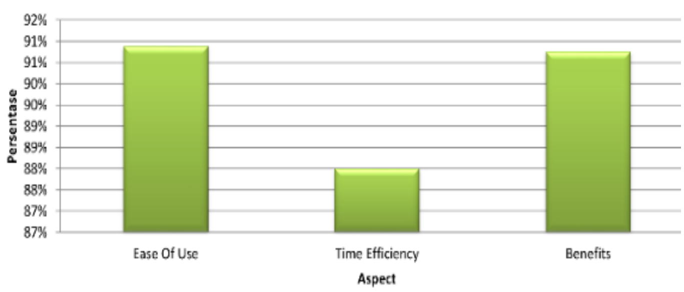

Figure 3. Practicality result

The exploration doesn't stop at the mere presentation of results(Efriani et al., 2020). Delving deeper into the discussions surrounding the Flipped Classroom paradigm and Guided Inquiry Syntax, it becomes evident that the future of chemistry education – and arguably broader scientific education – leans heavily towards these methodologies(Care et al., 2018). Their combined efficacy, as demonstrated in this research, provides a compelling argument for broader adoption.

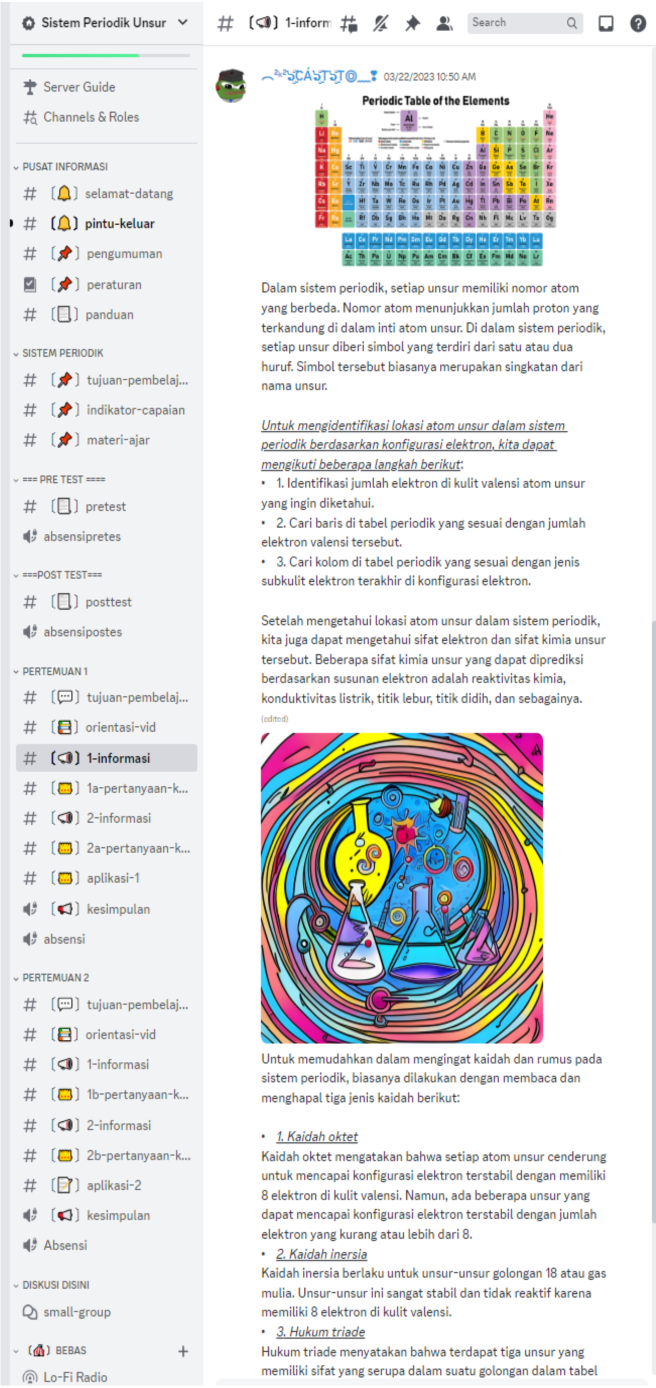

Figure 4. How Guided Inquiry Looks inside Discord System

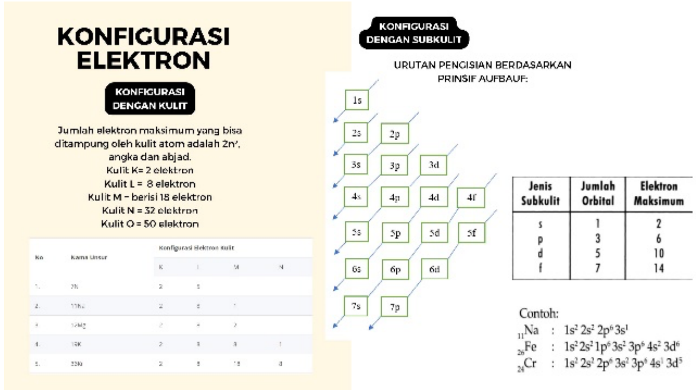

Figure 5. Learning Media that integrated inside

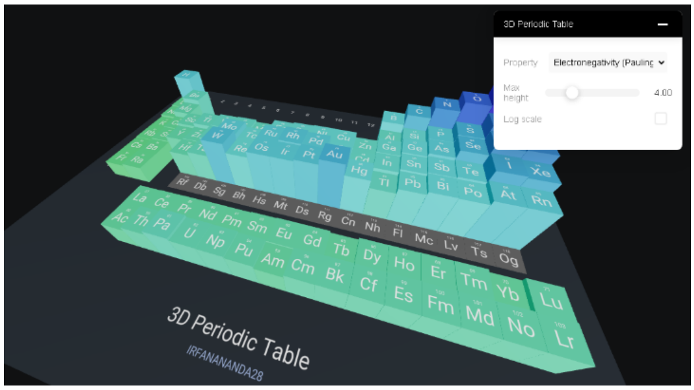

Figure 6. Model that will help student obtaining the information

The prominence of the Merdeka Curriculum in the Indonesian education landscape necessitates tools and resources that cater to its unique demands. The curriculum emphasizes independence in learning, aligning seamlessly with the Flipped Classroom approach where students take proactive roles in their educational journeys. The synergy between the curriculum's vision and the teaching methodologies adopted in this study serves as an affirmation that education is moving in the right direction, adapting to the needs of the modern learner.

Furthermore, the integration of the Guided Inquiry Syntax cannot be understated. It functions as a bridge between traditional learning and inquiry-based exploration, nurturing students' innate curiosity. By guiding them through structured yet open-ended inquiries, the content ensures that students don't merely absorb information but actively engage with and challenge it. This dynamic is pivotal in cultivating a generation of thinkers and innovators, especially in a discipline as intricate and ever-evolving as chemistry.
Another layer worth discussing is the role of digital transformation, as embodied by the Industry 4.0 revolution(Azis et al., 2020). With technology becoming an integral facet of education, the content's adaptability to various digital platforms will be crucial. Although this study didn't delve deeply into this aspect, future research might focus on optimizing the creative content

for digital consumption, ensuring that it remains relevant in an increasingly tech-driven educational landscape(Cholily, 2020).

The concept of validity and practicality in educational tools, particularly in a subject as intricate as chemistry, goes beyond simple quantitative assessments. The validity and practicality of the creative content developed in this research, as demonstrated by the data obtained from expert and the student , attest to its impact. However, what does validity and practicality truly encompass within the context of this investigation? The validity and practicality of the creative content and guided inquiry approach were further evidenced by the seamless execution despite a shift to entirely online learning. As documented in the accompanying materials, the course was conducted remotely, with students participating from home due to any emergency constraints. This transition to a virtual environment did not adversely affect the delivery of the creative content and guided inquiry exercises. Students maintained active engagement through online guided inquiry tasks and multimedia resources.

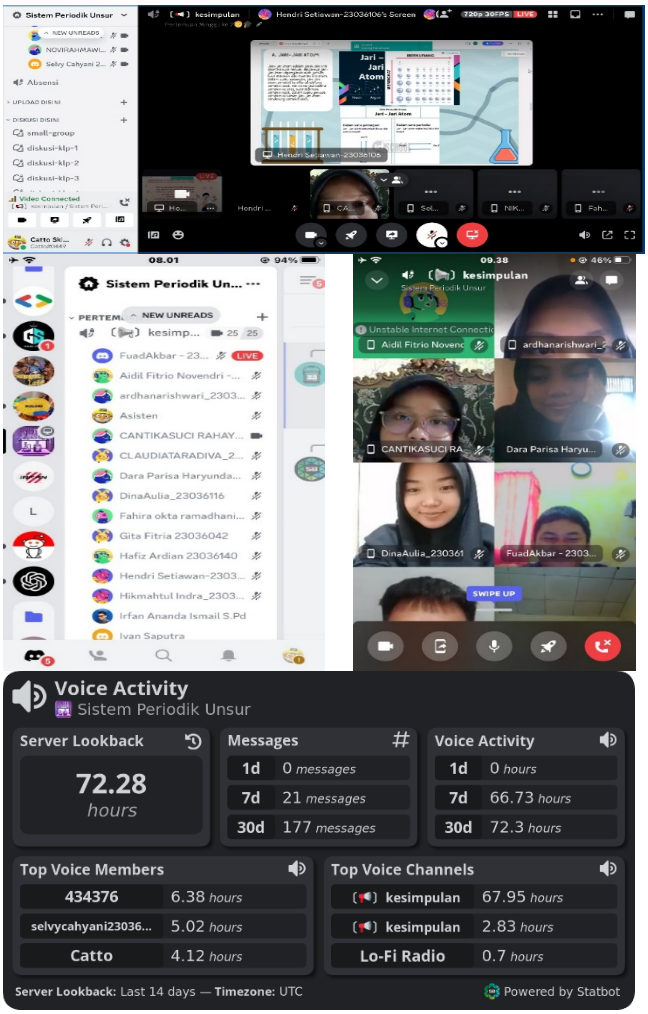

Figure 7. learning activity can be done full inside Discord

The attached records of the online course activities and student participation provide qualitative evidence that the intervention was successfully adapted for distance learning. The continued positive impact on student outcomes underscores the potential for this approach to enhance engagement and comprehension in both traditional classroom and remote settings.

At its core, the development and validation process in this research was gauged by the students' enhanced comprehension of the Periodic System. However, it's essential to understand that true development is multifaceted. It's not just about how well students can regurgitate information but how deeply they internalize, relate to, and apply this knowledge in diverse scenarios.

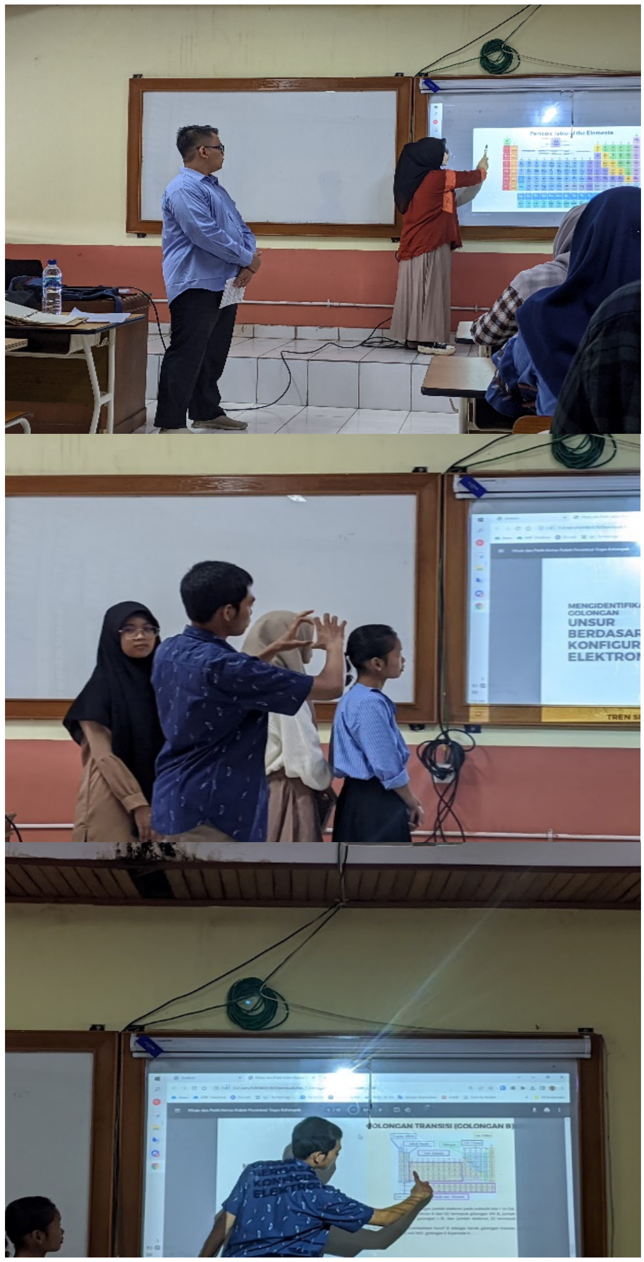

Figure 8. student shown her understanding by explain the answer of the key question

The creative content, enriched with the Guided Inquiry Syntax, inherently promotes this deeper level of understanding(Hurst et al., 2019). By allowing students to actively question, explore, and derive insights, they transition from passive learners to active knowledge seekers. This, in many ways, is the epitome of a valid and practical development.

While this study provides promising evidence for the efficacy of a flipped classroom model combined with guided inquiry in enhancing first-year chemistry students' learning, it is essential to position our findings within the broader landscape of research on active learning approaches in chemistry education. A systematic review by (Ješková et al., 2022) analyzed over 50 studies implementing various student-centered teaching techniques in college chemistry classrooms. The meta-analysis overwhelmingly showed that active learning improves student performance across multiple metrics compared to traditional lectures.

Specifically examining the flipped classroom approach, (Ryan & Reid, 2016) noted consistent positive impacts on student learning outcomes across disciplines, including a marked improvement in chemistry students' conceptual grasp of abstract topics like thermodynamics and reaction kinetics. However, they also highlighted the need for further research on the nuances of implementing flipped learning in chemistry education. Our study adds to this body of knowledge by demonstrating that coupling a flipped classroom pedagogy with guided inquiry-based activities can enable first-year students to deeply engage with the complex Periodic Table concepts.

Additionally, building on the work of (Michael R., 2005) and (Gormally et al., 2009) underscoring the merits of guided inquiry for chemistry instruction, our findings showcase how structured, facilitator-led inquiry can make abstract concepts more accessible to students struggling with the fundamentals. The adaptable multimedia materials developed through this study allow educators to tailor inquiries to students' pace of learning, while the overall guided discovery process helps solidify conceptual knowledge.

Moreover, our work aligns with (Jong, 2005) emphasis on the periodic table's visual and spatial elements that often pose comprehension challenges. By adopting multimedia formats like interactive maps, infographics, and models, the instructional materials designed here leverage visual cognition to mitigate these learning barriers. This adds a novel dimension to existing literature at the intersection of cognitive science and chemistry education.

Our promising results also mirror (Sun et al., 2018) report highlighting the effectiveness of flipped classrooms combined with digital technology in enhancing Chinese high school students' retention and higher-order application of chemistry knowledge. However, unlike (Sun et al., 2018) focus on a specific technological platform, our approach prioritizes pedagogical principles over tools, designed to be adaptable to diverse educational contexts. This distinction enables broader adoption across institutions with varying access to technology.

Furthermore, while excellent prior research has examined flipped active learning in chemistry lecture halls (Waer, 2021) and laboratories, first-year courses have received relatively less focus. Given that introductory courses play a pivotal role in nurturing students' interest in chemistry, our work addresses a crucial gap. The guided inquiry-based activities can spark curiosity and engagement right from the foundational level, helping shape undergraduates' trajectories in the discipline(Al-Balushi et al., 2017).

Another dimension to consider is the longevity and retention of knowledge(Mawardi et al., 2020). While immediate post-intervention tests might indicate an improvement, the real measure of development lies in how well these concepts are retained over a more extended period(Fosu et al., 2019). Given the systematic and engaging nature of the content, it can be postulated that students are more likely to remember and apply these concepts long after their initial encounter.

Moreover, the development process also encompasses the broader influence of this content on students' attitudes towards chemistry(Mawardi & Fitriza, 2019). By presenting the Periodic System in an innovative, relatable manner, the research potentially diminishes the intimidation factor often associated with complex scientific concepts. This could lead to a heightened interest in chemistry, fostering a culture of continuous learning and exploration(Rahayu et al., 2022).

Additionally, the validity and practicality of the content are also reflected in its adaptability(Adamson & Darling-Hammond, 2015). Given the ever-changing educational landscape, especially with the integration of technology and the demands of the Merdeka Curriculum, content that remains flexible and can be tailored to various teaching methodologies and platforms inherently possesses a higher development quotient(Rahmiati & Mawardi, 2016).

In wrapping up this discussion on development, it's pivotal to acknowledge the iterative nature of educational research(Adila et al., 2017). While this study has illuminated significant pathways in enhancing chemistry education, the journey of refining and optimizing content for maximum validity and practicality is ongoing(Rauch, 2015). Feedback loops from students, educators, and stakeholders, coupled with consistent research, will ensure that the content remains relevant, engaging, and, above all, valid and practical in its pedagogical mission.

Conclusion

The realm of chemistry education, particularly at the State University of Padang, is experiencing significant transformations, necessitating materials and approaches that align with the modern student's needs. This investigation, focused on the creation and validation of inventive content for the Periodic System, has revealed a promising direction. By employing the Plomp development model and merging the Flipped Classroom paradigm with Guided Inquiry Syntax, we have devised a pedagogical instrument that not only meets the requirements of the Merdeka Curriculum and the challenges of Industry 4.0 but also demonstrates validity and practicality.

The validation outcomes, exhibiting high construct and content validity, attest to the scholarly rigor and pertinence of the developed content. Combined with its proven practicality, it presents a persuasive solution for first-year chemistry students, potentially cultivating a more immersive and engaging comprehension of the Periodic System.

Nonetheless, the process of innovation and enhancement is unending. While this study represents a substantial milestone, the broader objective is to continuously adapt and refine these educational resources, ensuring they remain in sync with the evolving demands of students and the dynamic nature of global education.

Fundamentally, this research highlights the immense potential of creative content in reimagining educational experiences, establishing a solid groundwork for future pursuits in chemistry education and beyond.

In further contemplation, the importance of this study transcends the boundaries of the State University of Padang. By pioneering an approach that effortlessly integrates the Flipped Classroom methodology with Guided Inquiry Syntax, a template is established for other institutions, educators, and stakeholders to adopt and implement. This applicability across contexts attests to the far-reaching consequences of the research.

The validity and practicality metrics, grounded not only in quantitative data but also in the qualitative transformation observed in students' engagement and comprehension, elucidate the profound impact of the creative content. However, the narrative does not end here. The perpetually changing educational landscape, propelled by technological advancements and shifting global paradigms, necessitates a proactive approach. The content, while highly valid and practical now, will require ongoing updates and revisions to stay abreast of emerging pedagogical trends and student needs.

Feedback mechanisms, both formal and informal, will be crucial in this iterative process. Collaborating with students, educators, and experts will yield invaluable insights, ensuring the content's perpetual evolution and optimization. This cooperative approach will also enhance the content's scalability, enabling its potential adoption in various educational environments.

Furthermore, the emphasis on creative content, as underscored in this study, serves as a rallying cry for educational stakeholders. In an era where rote memorization is increasingly outdated, and critical thinking is essential, the transition towards innovative, interactive content is not just advisable, but mandatory.

In conclusion, the journey undertaken in this research, replete with discoveries and achievements, is merely the commencement. The intertwined trajectories of education and innovation are extensive and ever-changing. This study, with its insights and methodologies, functions as both a guiding light and a challenge—a guiding light revealing the transformative power of creative pedagogy, and a challenge to persistently push the limits, ensuring every learner is prepared to tackle the intricacies of the contemporary world.

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Author Contributions

Mawardi was instrumental in the conceptualization, initiating, and developing the primary concept and scope of the research. He also designed the research methods, undertook primary data collection efforts, spearheaded quantitative and qualitative data analysis, prepared the initial versions of the manuscript, and was actively involved in subsequent revisions. Meanwhile, Irfan Ananda Ismail conducted an exhaustive review of existing literature, assisted in data collection, played a pivotal role in interpreting research findings, provided critical feedback on the manuscript's drafts, contributed to the creation of visual representations of the data, and managed the overall project, ensuring its timely completion.

Okta Suryani contributed significantly to the development and validation of the creative content, as well as the implementation of the Guided Inquiry Syntax. She also played a crucial role in adapting the content for distance learning and evaluating in both traditional and remote settings. Okta was actively involved in refining the content based on feedback from students and educators, ensuring its relevance and practicality.

Munadia Insani was responsible for overseeing the statistical analysis of the data, ensuring the accuracy and reliability of the results. She also contributed to the interpretation of the findings, providing valuable insights into the implications of the research for chemistry education. Munadia was involved in the drafting and revision of the manuscript, particularly in

sections related to data analysis and interpretation, and she approved the final version of the manuscript.
Alizar Ulianas assisted with literature review, data analysis, and drafting sections of the manuscript. Mulyanti Contribution participated in study design, data collection and interpretation.
Both Okta Suryani and Munadia Insani, along with Mawardi and Irfan Ananda Ismail, have thoroughly reviewed and approved the final version of the manuscript. Alizar Ulianas and Mulyanti Contribution also reviewed and approved the final manuscript.

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Conflicts of Interest
The authors earnestly declare that there exists no conflict of interest concerning the research, authorship, and publication of this article. We affirm that there are no known competing financial interests, affiliations, partnerships, or personal relationships that might have influenced the outcomes and interpretations presented in this study. Throughout the duration of the research and the preparation of this manuscript, all authors have remained committed to maintaining the highest standards of scientific integrity and transparency. Any potential influence or bias, financial or otherwise, that could undermine the objectivity, authenticity, and validity of our findings has been conscientiously avoided. Furthermore, all data and methodologies are available for scrutiny and are bereft of any undisclosed influence. The collective aim of the authors has been, and remains, the objective dissemination of genuine, unbiased research for the benefit of the broader academic community and the public at large.

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