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# The creativity of chemistry education students in the digital age

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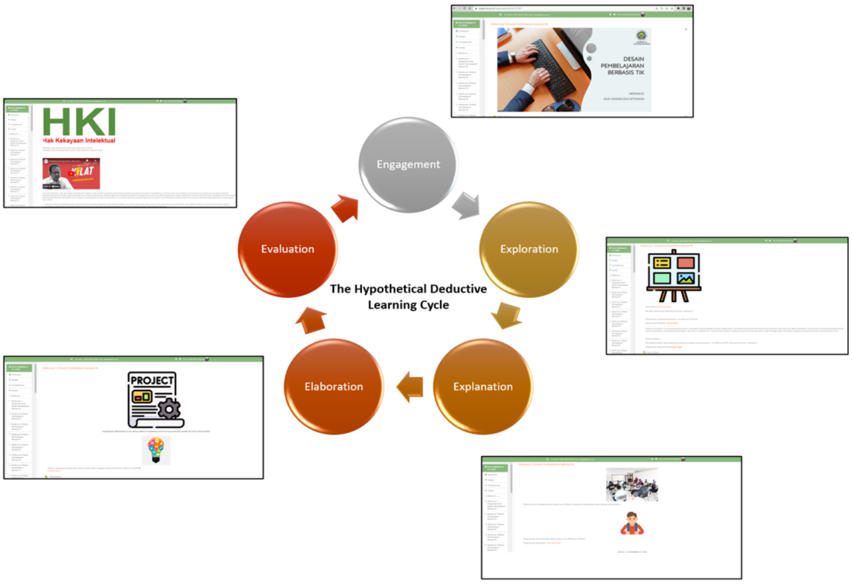
## Abstract

The creativity of chemistry education students in the digital era is an exciting topic for discussion, given the critical role of creativity in developing innovations for prospective chemistry teachers. This study explores the creativity of chemistry education students in the digital era. The research method used is descriptive qualitative with data collection techniques through learning with hypothetical deductive learning cycle models, interviews, and observations. The research participants consisted of twenty-nine fifth-semester chemistry education students. The results showed that 70% of chemistry education students were in the creative category, and 30% were in the moderately creative category. This study provides essential information about the creativity of chemistry education students in facing the digital era, as well as challenges and opportunities that must be considered in the development of chemical education innovations in the digital era.

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1. creativity;
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3. digital era.

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### Highlights

- HDLC model with digital integration enhances chemistry students' creativity.
- 70% of students exhibit high creativity through project-based digital learning.
- Student-created digital products are registered for Intellectual Property Rights.
- AR, virtual labs, and multimedia tools improve understanding of chemical concepts.

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# 1. Introduction

In an ever-evolving educational landscape, the digital era's emergence has significantly changed how students learn and educators teach (Wilcox *et al.*, 2017). With the rapid integration of technology into the classroom, the dynamics of knowledge acquisition have been reshaped, leading to new challenges and opportunities for creativity across multiple disciplines (Afrianto, 2018). Among these disciplines, Chemistry education is an essential field of study, as it is essential in nurturing the next generation of scientific minds and problem solvers (Pagliaro, 2019). As the world becomes increasingly interconnected and dependent on digital tools, students' demand for creative problem-solving skills is increasing (Astuti *et al.*, 2019; Setiawan *et al.*, 2023).

As we study creatives, we must recognize that creativity is not limited to artistic expression. Creativity refers to generating new ideas, solutions, and perspectives in the educational context, fostering critical thinking and innovation (Oppert *et al.*, 2023). Today, these creative ideas are increasingly intertwined with digital tools and technologies, influencing the way Chemistry is taught and understood (Pont-Niclòs *et al.*, 2023). The tendency of students who studied from home for two years due to the COVID-19 pandemic changed their learning chemistry (Setiawan and Rosli, 2022). Students are used to learning from home with a learning management system provided by education providers (Setiawan and Rosli, 2023). However, the measurement of student creativity is rarely carried out due to the limited instruments and measurement methods used (Haviz *et al.*, 2020).

The study of measuring students' creative abilities in the digital era is essential because digital transformation affects how students create and learn (Oppert *et al.*, 2023). This measure helps understand the role of technology in the creative process, identify students' creative potential, and improve their creative skills. In addition, the results of this measurement help refine the curriculum and encourage educators to create innovative learning environments (Akib and Muhsin, 2019). This is important to prepare students to face future challenges that are increasingly complex in technological developments (Yang *et al.*, 2021). Thus, measuring creativity in the digital era is essential for creating a generation of creative students ready to face changing times (Redhana, 2019).

Relevant learning models can optimize creativity (Weng *et al.*, 2022). One such model is the hypothetical deductive learning cycle (HDLC), which can be adopted with abstract, concrete, and algorithmic chemical concepts (Lawson, 1995). The HDLC learning model is very flexible and can be applied according to technological developments and coupled with existing digital platforms (Setiawan, 2017).

The digital age has ushered in an era of limitless possibilities for teaching and learning. Modern educational institutions integrate multiple digital platforms, software applications, and interactive learning environments to engage students innovatively (Afrianto, 2018; Turiman *et al.*, 2012). Chemistry education has also undergone a paradigm shift, with instructors utilizing digital simulations, augmented reality, online labs, and collaborative platforms to deliver engaging and interactive lessons (Khery *et al.*, 2020; Setiawan *et al.*, 2020). Consequently, students are encouraged to adopt a creative approach to their learning, connecting abstract concepts and real-world applications (López, 2022).

This study aims to determine the digital era's impact on Chemistry education students' creativity. By examining the creative abilities of chemistry education students, we seek to identify ways in which these resources influence students' creative thinking processes, problem-solving abilities, and overall academic performance. In addition, we will explore the challenges and barriers that may arise when integrating technology into the teaching of Chemistry education and potential strategies to overcome these obstacles. The findings of this study have significant implications for educators and policymakers. By understanding how the digital age influences the creativity of Chemistry education students, educators can adapt their teaching methodologies to nurture students' creative potential better. Policymakers can also use this insight to develop practical guidelines for integrating digital technologies into curricula, ensuring that technology is a catalyst for creativity rather than a distraction.

# 2. Experimental

This research is descriptive and uses qualitative methods. Learning occurs face-to-face and online using a learning management system (LMS). The LMS has arranged learning videos, modules, virtual discussion forums, virtual meeting links, and quizzes. All student activities are fully documented in the LMS. The learning method applied is a hypothetical deductive learning cycle of five phases (Lawson, 1995; Setiawan, 2017).

The research was conducted for five months at the end of 2022 at a public university in Indonesia. Twenty-nine undergraduate chemistry education students who took the school chemistry laboratory management program in their fifth semester participated in this study. The data collected includes questionnaires, interviews, and learning achievement. At the end of the semester, students voluntarily filled out a questionnaire about their opinion of the course, and all students answered the questionnaire. The questionnaire consists of 9 items with a Likert scale of five, from strongly agree to disagree strongly. The question focuses on the participants' views of their interests during lectures.

The interviews were deliberately structured to complement the findings in the questionnaire. Interview participants were selected to represent variations in responses from the questionnaire (Nida *et al.*, 2020). The interview was conducted for 15-20 minutes. It was recorded, transcribed, and qualitatively analyzed (Nida *et al.*, 2021). All interview excerpts are translated from Indonesian. Data is provided by participants voluntarily and handled anonymously. Collecting and handling data complies with legal requirements for empirical research ethics with humans in relevant departments. The dean of the faculty granted permission to use the data.

# 3. Results and discussion

Several factors should be considered in designing the right teaching approach for Information and Communication Technology (ICT) Based Learning Design courses. One way is to evaluate the appropriate pedagogical model. Among the various learning theories, the HDLC is considered the most appropriate approach to apply in learning in this class. HDLC illustrates that students actively manage the information they acquire and rearrange it to acquire and retain new knowledge. In addition, this approach emphasizes the idea that students can further develop knowledge by building on previous information and experience through a series of different activities and assessments (Barnard *et al.*, 2009; Shetu *et al.*, 2021). In the HDLC learning model, new information is presented in a way that connects and builds on previous concepts. Discussions on technical topics, practical applications, or problems related to ICT-based learning designs are held interactively. Assessments are given to test students' understanding and problem-solving skills. These strategies provide effective learning because this method emphasizes the most relevant and applicable learning concepts in the digital era. Creativity is an essential aspect of the 21st-century learning approach. In this context, Negovan *et al.* (2015) found that students in face-to-face and distance learning highly perceive learning as understanding, which includes increasing memory and knowledge and applying what is already known. The HDLC learning model applied in the ICT-Based Learning Design course supports the development of students' creative abilities because it allows them to connect new information with previous experiences and face challenges in designing innovative learning according to the demands of the times. Thus, the HDLC strategy applied in this lecture aims to maximize students' role in the learning process and equip them with critical, creative abilities in dealing with the complexity of problems in the 21st century.

The ICT-Based Learning Design course was held face-to-face for the first time after the COVID-19 pandemic, which hit the world for about two years. Based on **Fig. 1**, twenty-nine students taking this course are fifth-semester chemistry students, dominated by female students. Lectures are held for 16 weeks, and lessons use the HDLC learning model. In addition to face-to-face lectures, learning also uses a learning management system provided by the university. Utilizing this LMS provides an advantage for educators to monitor the learning process of students in real-time (Setiawan and Rosli, 2023).

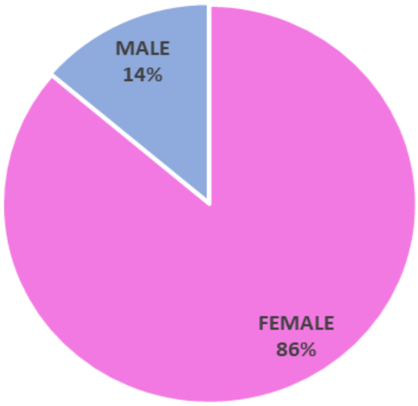


**Figure 1**. Gender of participants.
**Source:** Elaborated by the authors.

Based on **Fig. 2**, student learning achievement for one semester following an ICT-Based Learning Design course is good. As many as 14% of students got B+, 41% of students got A-, and 45% of students got A. Learning achievement is obtained from discussion scores, presentation scores, and project exams, with a weighting of 30% for discussion scores, 30% for presentation scores, and 40% for project exams.

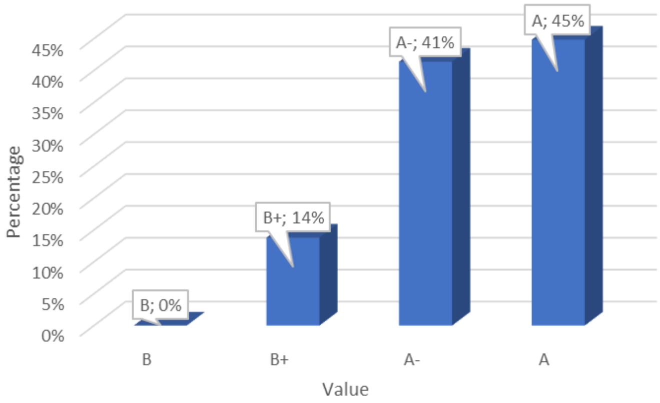


**Figure 2**. Learning achievement.
**Source:** Elaborated by the authors.

Most students (72%) agree and strongly agree with groupings in class. Grouping is done randomly, hoping that students can exchange opinions and help each other in this lecture. Only 10% of students disagree with this grouping. The results of the interviews revealed that there needed to be a better match in working together in groups. Typical examples were: "*I have invited group mates to discuss problems in making digital products, but group mates gave a slow response, so I did it myself.*"; "*My group mates are too busy with activities outside the campus, so it is difficult for us to discuss.*"

Based on **Fig. 3**, most students (69%) like learning with the HDLC model, and only 7% of students do not like it. Almost all participants (90%) stated that their creativity had increased in this lecture, and 86% of students stated that they were satisfied with the results of the products that had been made. This is supported by interview data collected at the end of the course. The analysis results show that most students stated that the part they liked the most was the project of making digital media and product presentations. A typical example is: "*I learned a lot about making digital media... In completing the project, I learned how to make moving image animations about abstract chemical concepts and create a website that looks attractive and can be integrated with smartphones. This is a new thing for me, who incidentally is a chemistry education student.*"; "*I like the product presentation session where each group presents their best work and shows the creativity of each group... this gives me ideas to develop the products I have made.*" (Setiawan, 2017) states that HDLC learning allows students to explore the potential within them. The HDLC phase allow teachers to direct students in learning concepts (Lawson, 1995). This positively impacts student learning outcomes in the ICT-Based Learning Design course.

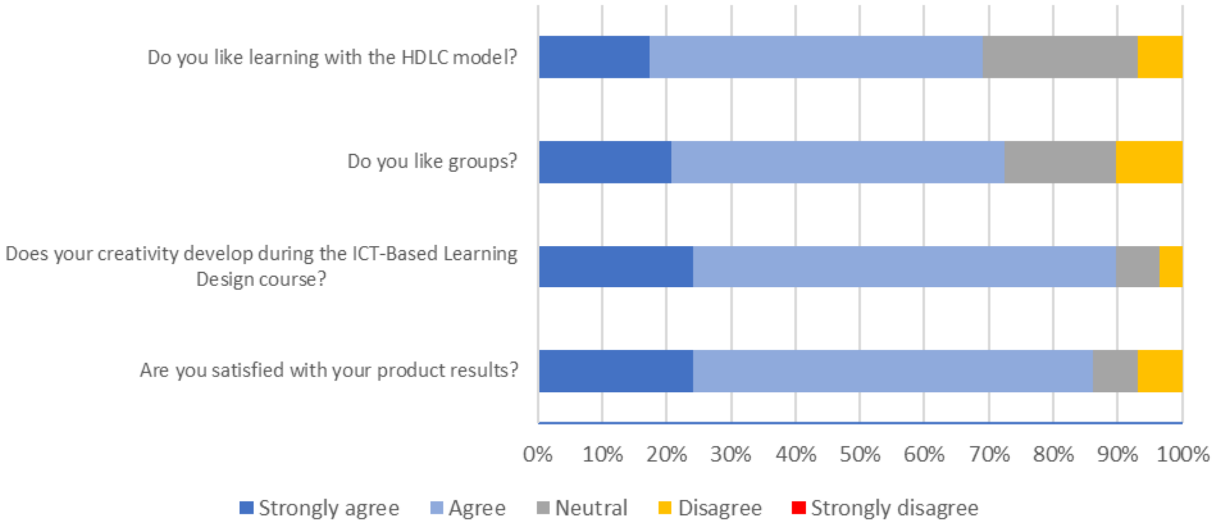


**Figure 3**. Students' experiences (*N*=29).
**Source:** Elaborated by the authors.

During the lecture, students explained the learning objectives and class activities using the HDLC learning model. The lesson plan proposed by (Setiawan, 2017) is similar in several ways. The new feature implemented in this unit is an integrated LMS recorded on a university server.

Students carry out learning activities in sixteen meetings, eight of which are asynchronous and eight synchronous, with an asynchronous time of 100 minutes each. The process of these activities can be seen in **Fig. 4**.


**Figure 4**. Students' experiences.
**Source:** Elaborated by the authors.

Students are asked to pay attention to the videos prepared in the LMS at the engagement stage. Students are asked to work in groups and discuss videos about problems in chemistry education in Indonesia. From the video, they were asked to identify the advantages and disadvantages of learning chemistry in Indonesia. Groups that have obtained the advantages and disadvantages of learning chemistry are asked to determine the parts that must be by the regulations and solutions that apply to these problems. In the exploration phase, the results of group discussions were responded to by other groups in online discussion forums (chat). Each group will argue with each other about the concepts they understand. The group will test the hypothesis and try to solve the problem by making digital learning media. In this phase, student creativity will be optimized because they must be able to create digital learning media that are in line with current developments. At the explanation stage, each group tested digital learning media on a respondent, so they knew the advantages and disadvantages of digital media products. This data will be used to revise digital media products. At this stage, the lecturer provides reinforcement and synchronization of the concept of chemistry learning media. Each group presents digital learning media products in class in the elaboration phase. This is where creativity between groups will be pitted. The digital media products offered will be discussed in class, and suggestions for further development will be obtained. The last phase is the evaluation phase, where the lecturer will assess the product through presentations and interviews (**Table 1**). The evaluation criteria are product authenticity, accuracy of chemical concepts, suitability of digital media, and fluency and flexibility in discussions.

From the learning results presented in **Fig. 5**, it is known that students' presentation abilities show promising results. The digital media products are of good quality, and all digital media products are registered to obtain Intellectual Property Rights (IPR). **Figure 6** shows that 70% of students have creativity criteria, and only 30% have creative enough criteria. The interviews showed that the students enjoyed the lectures and felt facilitated by them so that their creativity could develop optimally. One example: "*I feel happy with this lecture because I can create a digital application that can be useful for learning. Besides that, this application can be widely marketed and gain profit for the developer. My creativity is maximized in designing the application so that readers do not get bored looking at the application; There are many challenges in developing the digital media that I make, so my creativity is tested to give maximum results*".

**Table 1.** HDLC in ICT-based Learning Design courses.

| Phase | Description | Activities | Creativity |
|---|---|---|---|
| Engagement | Arouse students' initial understanding and study problems in the world of chemistry education | • The lecturer pointed out the problems faced in education, namely the problem of students' difficulties in learning chemistry.<br>• Students make temporary guesses or hypotheses on existing problems.<br>• Students look for solutions to problems set in their groups. | • Be creative in solving the problems presented in the video |
| Exploration | Problem-solving exploration | • Students design a problem-solving design according to the problems set by the group.<br>• The study of making digital media suitable for each group.<br>• Make digital media according to the design that has been made. | • Creative in designing problem solving |
| Explanation | Apply the product that has been made | • Digital media was tested on one respondent, and feedback was received for further improvement and development.<br>• Digital media is improved according to the suggestions of the respondents. | • Creative in digital media application |
| Elaboration | Got a question? Get connected and participate in classes. | • Presentations made in class.<br>• Discussion of the advantages and disadvantages of digital media.<br>• Making videos for digital media products.<br>• Manufacture of manuals for digital media products. | • Creative in making digital media product videos |
| Evaluation | Assess your understanding of the problems uploaded through the exam | • The assessment was conducted by interviewing the results of making digital learning media products. | • Creative in making digital media |

**Source:** Elaborated by the authors.

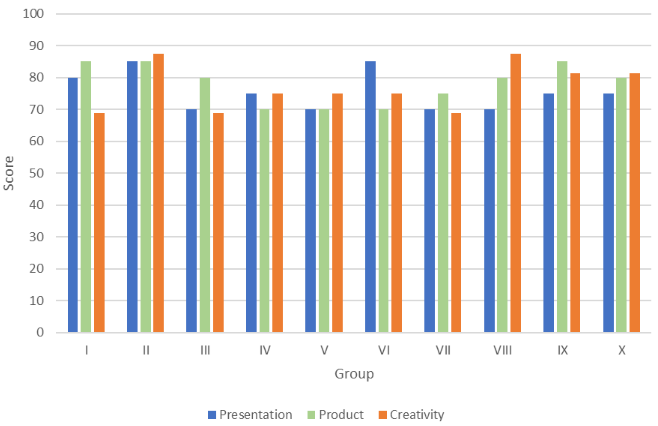


**Figure 5.** Scores of presentation, product and creativity assessment results.
**Source:** Elaborated by the authors.

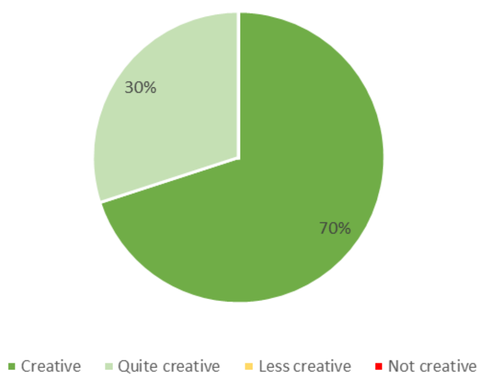


**Figure 6.** Percentage of creativity.
**Source:** Elaborated by the authors.

In the explain phase, there are limited trial activities for respondents. This is a new activity for chemistry education students because the product is directly tested on respondents. This experience makes students develop quality products. The results of the interviews show that with this provision in place, they prepare digital media seriously for fear of disappointing the respondents. An example of an interview result: "*I prepared this extra better because I was worried that the respondent would reproach me if the product were bad.*" The elaboration phase requires groups to present digital media products in front of the class. This stage is the stage that students look forward to the most because they can present their product results in front of the class by showing videos of digital media products. Students' creativity in making videos of digital media products is dominant in this phase. The final phase is evaluation; in this stage, students present the final product to the lecturer. The presentation includes product videos, digital media products, manuals, and a statement letter for filing Intellectual Property Rights regarding digital media products.

Research has demonstrated that learning in this manner can be remarkably advantageous for students, as it has been shown to amplify their creativity (Williamson *et al.*, 2015). Students can foster their creative aptitude by furnishing a properly conditioned learning environment (Ojha, 2016; Tubb *et al.*, 2020). Notably, digital learning media products have been found to impact student creativity significantly, as evidenced in **Fig. 7**. Embracing this form of learning can unlock each student's creative potential to its fullest extent (Thompson, 2017).

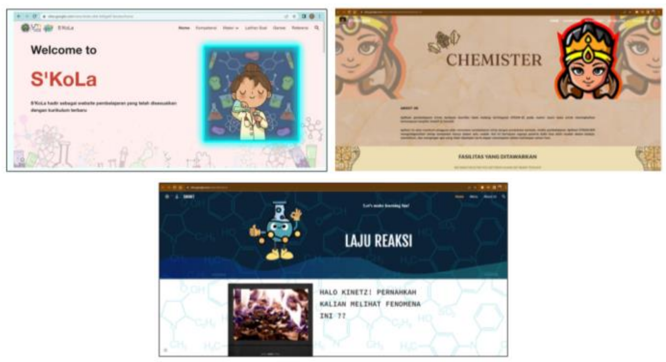


**Figure 7**. Digital learning media products.
**Source:** Elaborated by the authors.

## 4. Conclusions

This research provides insight into the intersection between technology and creativity in the context of chemistry education that is developing in the 21st century. The results showed that 70% of chemistry education students had creative criteria, while 30%

had creative enough criteria. Through the integration of technology and the development of creativity, students are expected to be able to develop competencies that are relevant to the times, support scientific progress, and contribute to solving complex problems faced by global society.

## Authors' contribution

**Conceptualization**: Nur Candra Eka Setiawan; **Data curation**: Nur Candra Eka Setiawan; **Formal Analysis**: Nur Candra Eka Setiawan; **Funding acquisition**: Nur Candra Eka Setiawan; **Investigation**: Nur Candra Eka Setiawan; **Methodology**: Nur Candra Eka Setiawan; **Project administration**: Nur Candra Eka Setiawan; **Resources**: Nur Candra Eka Setiawan; **Software**: Herunata Herunata; **Supervision**: Mohd Shafie Rosli; **Validation**: Herunata Herunata; **Visualization**: Nur Candra Eka Setiawan; **Writing – original draft**: Nur Candra Eka Setiawan; **Writing – review & editing**: Nur Candra Eka Setiawan

## Data availability statement

The data will be available upon request.

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## Conflict of interest

The authors declare that there is no conflict of interest.

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