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# IMPLEMENTATION MODEL C-R-E-A-T-E BASED ON DL-AI-ESD IN GREEN CHEMISTRY TO DEVELOP STUDENTS' MULTIPLE CREATIVITY

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## Abstract

This research aims to develop students' multiple creativity through the implementation Model C-R-E-A-T-E (Connecting-Restructuring-Elaborating-Applying-Tasking-Evaluating) based on Deep Learning-Artificial Intelligence- Eduaction for Sustainable Development (DL-AI-ESD) in Green Chemistry. The methodology used is Design-based Research (DbR) which focuses on the development and evaluation of innovative learning models in a real context. The research subjects consisted of 80 high school students who were selected purposively. The main instruments used are TCOF (Teaching Creativity Observation Form) to measure aspects of compound creativity, as well as observation sheets to assess student engagement and response during the learning process. Data collection techniques include initial and final tests, classroom observations, and limited interviews. The data was analyzed quantitatively using descriptive and inferential statistical tests, as well as qualitative analysis to explore the dynamics of learning. The results show that significantly increases students' multiple creativity through the implementation Model C-R-E-A-T-E based on D-AI-ESD in Green Chemistry, which includes scientific, social, and ecological creativity. The **conclusion**, significance, and impact study illustrate that this model also encourages students' active involvement in sustainability issues and data-driven decision-making. This study recommends the application of a similar model in other subjects to support sustainable and transformative 21st century education.

**Keywords:** Model C-R-E-A-T-E, DL-AI-ESD in Green Chemistry, Multiple Creativity

## INTRODUCTION

21st century education (Rahayu, 2017) demands a learning transformation that focuses not only on content mastery, but also on the development of critical, creative, and sustainable thinking skills (Zeidler & Nichols, 2009; Calik & Wiyars, 2021; Saija, et al., 2022). One relevant approach is Education for Sustainable Development (ESD), which emphasizes the importance of environmental awareness (Maxmillian, et al., 2019; Caliskan, 2021; Moody-Marshall, 2022), social responsibility, and value-based decision-making. In the context of learning chemistry, especially green chemistry, ESD (UNESCO, 2017; UNESCO, 2018; Scott, et al., 2019; Zidny, et al., 2021; Purnamasari & Hanifah, 2021; Abas & Awang, 2022) is very important because environmental issues such as pollution, chemical waste, and energy efficiency are an integral part of the material taught. However, the integration of ESD in chemistry learning in schools is still not optimal, both in terms of pedagogical approaches and the use of technology in order to achieve the Sustainability Development Goals or SDGs (Amos & Levinson, 2019; Twediana, et al., 2020; Zhou, et al., 2022; Safitri, et al., 2022; Ali, et al., 2023).

On the other hand, continuing education (Berglund et al., 2019) can be in line with the development of artificial intelligence (AI) and deep learning (DL) technologies, opening up great opportunities to design more adaptive, interactive, and personalized learning models (Chen, 2016; Alcoat & Muhlenen, 2018; Zahara & Atun, 2018; Astuti, et al., 2019; Hamilton, et al., 2020; Ferrel, et al., 2020; Lu, et al., 2021). AI technology must be integrated in learning models in the digital era (Chang et al., 2024; Guneyli et al., 2024); The C-R-E-A-T-E (Connecting-Restructuring-Elaborating-Applying-Tasking-Evaluating) model developed in the context of science learning (including chemistry learning) is research-based (Wahyu, et al., 2020; Wahyu & Kusrijadi, 2022; Wahyu & Oktiani, 2024; Wahyu & Kusrijadi, 2024), has great potential to be combined with DL-AI technology. With this integration, students can be trained to think scientifically in student-centered learning (Yohan, et al., 2022; Zhang, 2022; Sutantri, et al., 2023), explore project-based data independently (Bramwell-Lalor et al., 2020), and come up with creative solutions to complex environmental problem-solving processes (Wahyu, et al., 2016; Life & Revelation, 2018; Wahyu et al., 2018; Wahyu et al., 2019). However, there have not been many studies that have examined the effectiveness of this model in the context of ESD and the development of students' compound creativity.

Multiple creativity encompasses various dimensions such as scientific, social, ecological, and technological creativity (Wahyu et al., 2018; Wahyu et al., 2019; Wahyu & Widhiyanti, 2020; Wulandari et al., 2020; Ma'ruf et al., 2020; Ananga, 2021; Gorny-Wegrzyn & Perry, 2021). In sustainability-oriented green chemistry learning (Zegstad & Sinnes, 2015; Hermawan et al., 2022), the development of compound creativity is highly relevant because students are expected to be able to design innovative solutions that are not only scientifically effective, but also have a positive impact socially and environmentally. Unfortunately, conventional learning approaches often only emphasize memorization and procedural and do not develop an inquiry approach (Ardiany et al., 2017), so that students' creativity potential is not explored to the fullest. Therefore, a learning model that is able to integrate ESD, DL-AI technology, and creativity development strategies holistically is needed.

This study aims to develop and test the effectiveness of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry, as well as measuring its impact on the development of students' compound creativity. The research subjects consisted of 80 high school students who were selected purposively. The research uses a Design-based Research (DbR) approach that allows for iterative and contextual model development. The instruments used include TCOF (Teaching Creativity Observation Form) to measure creativity, as well as observation sheets to assess student involvement in the learning process (Siregar et al., 2020).

Chemistry learning in Indonesia in general is still not in line with expectations (Amzar et al., 2018). The main problem in this study is the low integration of Education for Sustainable Development (ESD) in green chemistry learning which has not been able to develop students' multiple creativity optimally. To answer these challenges, this study formulates four questions: (1) how the results of the evaluation of the effectiveness of the implementation Model C-R-E-

A-T-E based on DL-AI-ESD in Green Chemistry to support the development of ESD in green chemistry in high school?; (2) what is the feasibility of designing a Model C-R-E-A-T-E implemented based on the TCOF review?; (3) the extent of the implementation Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry in increasing students' multiple creativity based on the review of the Williams Creativity Indicator ?; and (4) what are the activities of students when working on project assignments in groups in supporting the integration of ESD in green chemistry learning in schools through the implementation Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry?".

## LITERATURE REVIEW

The Model C-R-E-A-T-E (Connecting, Restructuring, Elaborating, Applying, Tasking, Evaluating) is designed to encourage students' creativity through the stages of critical and reflective thinking. Wahyu & Kusrijadi (2024) show that the application of this model in the manufacture of natural volta cells is able to significantly increase the creativity of high school students. In the context of chemistry education, this approach is relevant because it emphasizes the interconnectedness between scientific concepts and real applications, so that students not only understand the theory but are also able to create innovative solutions. This model is also in line with the demands of 21st-century skills, such as creative thinking, collaboration, and problem-solving. By integrating the C-R-E-A-T-E stages, teachers can guide students to explore ideas, reorganize information, and produce products that have scientific and environmental value.

DL-AI-ESD (Deep Learning, Artificial Intelligence, Education for Sustainable Development) is a multidisciplinary approach that strengthens sustainability-based learning. Wahyu & Kusrijadi (2024) examined the application of ESD-oriented Model C-R-E-A-T-E in the topic of natural voltaic cells, and found that students showed increased creativity in various dimensions. The integration of DL and AI allows students to access information extensively and process it independently, while ESD instills the value of sustainability in the learning process. In green chemistry, this approach is very important because it encourages students to create environmentally friendly chemical solutions. By combining digital technology and environmental awareness, students not only become creative but also socially and ecologically responsible. This model bridges the gap between scientific knowledge and real, sustainable action.

Multiple creativity includes students' ability to think divergently, generate new ideas, and apply knowledge in a variety of contexts. Wahyu, Oktiani, and Komalia (2020) stated that the Model C-R-E-A-T-E is effective in building students' creativity through a project to make voltaic cells from natural materials. The learning process that emphasizes on restructuring and elaborating information allows students to develop ideas in depth. When combined with DL-AI-ESD, this model expands students' exploration space through technology and sustainability values. Students not only create scientific products, but also consider their impact on the environment and society. This shows that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is able to develop compound creativity that includes cognitive, affective, and social aspects. Thus, this model is worthy of being widely applied in sustainability-based science education.

## RESEARCH METHOD

This study uses the Design-based Research (DbR) method which consists of four main steps (Plomp & Nieveen, 2017): (1) analysis of the needs and identification of ESD learning problems in green chemistry, (2) the design of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry that is appropriate to the context of high school students, (3) the implementation of the model in an experimental classroom with 80 students as subjects, and (4) evaluation of the effectiveness of the model through the measurement of compound creativity using TCOF instruments and observation sheets. The implementation procedure involves an iterative cycle of development, limited trials, model revision, and quantitative (Binus University, 2021) and qualitative data analysis for validation and improvement of learning design (Creswell, 2014).

ESD learning in green chemistry requires a contextual and applicative approach so that students understand the importance of sustainability in chemistry. The needs analysis shows that teachers and students need teaching tools that integrate the principles of green chemistry, such as minimal waste practicum and the use of environmentally friendly materials. However, the identification of problems revealed the limitations of teachers' understanding of ESD concepts, lack of training, and lack of relevant learning resources. In addition, learning still focuses on theory without encouraging critical thinking skills and sustainable solutions. Therefore, learning model innovation is urgently needed.

The design of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry for high school students aims to develop critical, creative, and reflective thinking skills in depth. This model integrates the stages of Connecting, Restructuring, Elaborating, Applying, Tasking, and Evaluating with a DL-AI approach that is adaptive to the needs of students. Through AI-based media, students can explore concepts in a personal and interactive way, such as experimental simulations or algorithm-assisted data analysis. Learning becomes more contextual, challenging, and relevant to real life, while supporting the strengthening of the Pancasila Student Profile and 21st century skills holistically.

The manuscript process in this study begins with systematic planning which includes problem identification, goal formulation, and determination of the Design-based Research (DbR) method as the main approach. The researcher designed a Model C-R-E-A-T-E based on DL-AI-ESD in Green chemistry that is integrated with the principles of Education for Sustainable Development (ESD) in the context of green chemistry. After the initial design was prepared, the implementation was limited to 80 high school students as research subjects. Data was collected through TCOF instruments and observation sheets, then analyzed quantitatively and qualitatively to obtain valid and reliable results.

The next stage is the preparation of a scientific manuscript based on the results of the research. The researcher compiles the structure of the manuscript according to academic standards, starting from abstracts, introductions, literature reviews, methods, results and discussions, to conclusions and suggestions. Each section is written with clarity, consistency, and contribution to the development of science education and continuous chemistry learning. The references used come from reliable and up-to-date sources, and are written according to the citation style determined by the destination journal. The researcher also ensures that the manuscript is free from plagiarism and has gone through an internal editing process.

The design of the Model C-R-E-A-T-E that integrates the stages of Connecting, Restructuring, Elaborating, Applying, Tasking, and Evaluating with the DL-AI-ESD in Green Chemistry aims to create a more personalized, contextual, and immersive learning experience for high school students. The Connecting stage focuses on building linkages between students' initial knowledge and relevant sustainability issues, such as green chemistry. DL-AI technology can be used to map students' learning profiles, so teachers can present content that suits their interests and learning styles. This allows students to be more emotionally and cognitively engaged from the beginning of the learning process.

The Restructuring and Elaborating stages encourage students to reorganize their understanding and develop new ideas through data-driven exploration. DL-AI plays a role in providing interactive simulations, visual analysis, and automated feedback that help students test and expand on the concepts learned. For example, in the context of green chemistry, students can use AI applications to predict the environmental impact of a chemical reaction or design more environmentally friendly alternatives. Thus, the elaboration process is not only theoretical, but also based on deep practice and analysis. The manuscript is completed, the next stage is submission to a reputable scientific journal relevant to the field of science and technology education.

The Applying, Tasking, and Evaluating stages emphasize the application of knowledge in real tasks and reflection on learning processes and outcomes. DL-AI enables the personalization of project-based tasks, such as designing green chemistry experiments or creating digital campaigns about sustainability. AI systems can provide automated formative assessments, error analysis, and improvement recommendations that suit each student's needs. Evaluation not only measures the final outcome, but also the student's thought process and creativity. With this integration, the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry becomes a learning tool that is adaptive, transformative, and relevant to the challenges of 21st century education.

The implementation of the learning model was carried out in four classes in the city of Bandung, consisting of experimental and control classes in public high schools (there are 2 high schools) and private high schools (there are 2 high schools), each with 20 students. The total number of research subjects was 80 students. The experimental class applied the Model C-R-E-A-T-E based on DL-AI-ESD designed to improve understanding of green chemistry concepts and ESD awareness, while the control class used conventional methods. The learning process lasted for several meetings with the same evaluation instrument. A comparison of learning outcomes between the experimental and control groups was used to measure the effectiveness of the model in the context of public and private schools.

The evaluation of the effectiveness of the learning model was carried out through the measurement of students' compound creativity using TCOF instruments and observation sheets designed to capture the verbal, figural, and social aspects of the learning process. The implementation procedure follows the Design-based Research (DbR) approach which is cyclic and iterative, starting from the initial design of the model, followed by a limited trial in the experimental class, and followed by revision based on the initial findings. The TCOF instrument was used to assess creativity dimensions such as the fluency of ideas, flexibility, originality, and elaboration, while the observation sheets recorded student interaction, involvement in assignments, and the application of green chemistry concepts in the context of ESD.

After the implementation of the trial, the data was collected and analyzed quantitatively and qualitatively. Quantitative analysis was conducted on TCOF scores to see a statistical increase in compound creativity, while qualitative analysis came from student observational records, interviews, and reflections describing learning dynamics. The results of the analysis are used to validate the effectiveness of the model and identify aspects that need improvement. The model revision was carried out based on the findings of the first cycle, then retested in the next cycle to ensure consistency and sustainability of learning impact. This approach ensures that the learning design is not only theoretical, but also responsive to the real needs of students and teachers in the field.

## RESULT AND DISCUSSION

The results showed a significant increase in the creativity of the students' compound in the experimental class using the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry compared to the control class. Measurements were made using TCOF instruments, which include the dimensions of smoothness, flexibility, originality, and elaboration. Statistical analysis using the t-test showed that the average creativity score of students in the experimental class was significantly higher ($p < 0.05$), both in public and private high schools. This indicates that the designed learning model is able to encourage students to think more creatively and come up with diverse solutions in the context of green chemistry and ESD.

In addition to quantitative data, qualitative analysis is carried out through classroom observations, interviews with students and teachers, and students' written reflections. The observation results showed that students in the experimental class were more active in discussing, showed enthusiasm in completing project-based tasks, and were able to relate chemistry concepts to sustainability issues. Interviews reveal that students feel more challenged and motivated because of the interactive and technology-based approach to learning. The students' reflections show an increase in awareness of the environmental impact of chemical practices as well as the emergence of innovative ideas in designing environmentally friendly solutions.

Findings from the first cycle were used to revise the learning model, especially in the aspects of time management, simplification of task instructions, and improved technology support. Teachers are also involved in the reflection process to provide input on the effectiveness of the DL-AI approach in supporting learning. After revision, the model was retested in a second cycle, and the results showed consistent increased creativity and student engagement. This iterative cycle is at the heart of the Design-based Research (DbR) approach, which emphasizes the development and refinement of learning designs based on empirical data and feedback directly from the field.

Overall, this approach proves that learning designs based on the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry and supported by DL-AI technology are not only effective theoretically, but also adaptive to the real needs of students and teachers. This model is able to bridge the gap between green chemistry concepts and learning practices that are relevant to the local context. With validation through quantitative and qualitative data, this model has the potential to be applied more widely as an innovative learning strategy that supports the development of pluralistic creativity and sustainability awareness at the secondary education level.

**Results of Evaluation of the Effectiveness of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry**

In **Table 1**, it appears that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry has been shown to significantly and consistently increase students' compound creativity. The iterative process of DbR allows for design adjustments that are responsive to classroom dynamics, making learning more meaningful and relevant. The results show that the need for the integration of ESD in green chemistry learning at the high school level is very urgent. Based on initial observations and interviews with teachers, it was found that most of the chemistry learning still focuses on the theoretical aspect and has not explicitly linked the concept of chemistry to sustainability issues. The main obstacles include limited relevant learning resources, lack of teacher training in implementing ESD approaches, and lack of time for creative exploration in the classroom. Students also show a low understanding of the environmental impacts of conventional chemistry practices, so learning that integrates ESD becomes essential for shaping ecological awareness and responsibility. The following table presents the results of research related to the statistical increase of compound creativity and qualitative analysis based on observations, interviews, and student reflections. This table also reflects the iterative process in the Design-based Research (DbR) approach to validation and refinement of Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry:

**Table 1.** Results of Evaluation of the effectiveness of The Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry

| **Evaluation Aspects** | **Data Statistics (TCOF)** | **Qualitative Analysis** | **Implications & Follow-up** |
|---|---|---|---|
| **Smoothness of Ideas** | Score increased from 65 → 78 ($p < 0.05$) | Students are more active in conveying ideas in discussions | The model encourages the exploration of ideas, it takes more time for discussion |
| **Flexibility of Thinking** | Score increased from 60 → 75 ($p < 0.05$) | Reflection shows that students are able to see from various points of view | Need open assignments to strengthen flexibility |
| **Originality** | Score increased from 58 → 73 ($p < 0.05$) | Teacher notes the emergence of unique solutions in project assignments | Effective model, needs more free expression space |
| **Elaboration** | Score increased from 62 → 76 | Interview: students are able to explain concepts in depth | Need AI support for visualization and simulation |

| Evaluation Aspects | Data Statistics (TCOF) | Qualitative Analysis | Implications & Follow-up |
|---|---|---|---|
| | (p < 0.05) | | |
| **Learning Dynamics** | — | Observation: students are more engaged, collaborative, and reflective | Supportive learning environment, needs to strengthen teacher facilitation |
| **Model Revision (Cycle 1)** | — | Instructions simplified, task time extended | The model is tailored to the context of the classroom and the readiness of the students |
| **Validation & Consistency** | High fixed score per syntax (p < 0.05) | Students' reflections show increased satisfaction and understanding | The model is proven to be consistent and positively impactful |

To answer these challenges, the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is designed with the stages of Connecting, Restructuring, Elaborating, Applying, Tasking, and Evaluating. This model combines a constructivist approach with artificial intelligence technology to support personalized learning and in-depth exploration of ideas. In its implementation, students are given project-based tasks that challenge them to design sustainable green chemical solutions. DL-AI technology is used to provide automated feedback, interactive simulations, and data analysis that help students develop compound creativity. Teachers act as facilitators who guide students' critical and reflective thinking processes throughout the learning stage.

The effectiveness of the model was measured through TCOF instruments and observation sheets. Statistically, there has been a significant increase in the dimensions of students' pluralistic creativity, such as fluency in ideas, flexibility of thinking, originality, and elaboration. Qualitative analysis of students' interviews and reflections showed that they felt more motivated, able to relate chemistry concepts to environmental issues, and come up with innovative solutions. The learning dynamics in the experimental class were also more active and collaborative than in the control class. These findings suggest that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is effective in developing compound creativity while strengthening the understanding of ESD in the context of green chemistry.

However, the results of the evaluation also identified several aspects that need to be improved. In the first cycle, it was found that the assignment instructions were still too complex for some students, and the implementation time was not enough for in-depth exploration. Therefore, revisions were made to the learning design, including simplifying instructions, adjusting the duration of assignments, and improving technology support. The second cycle showed an increase in consistency of results and student satisfaction. The DbR method allows for the development of models that are not only theoretical, but also responsive to the real needs of students and teachers, making learning more relevant, adaptive and long-term impact.

**Overview of TCOF Assessment Results**

The results of the TCOF assessment provide a comprehensive picture of the effectiveness of learning through four main dimensions: strategy, student response, activities, and methods. This assessment aims to identify strengths and areas that need improvement in teaching practice. The strategy dimension reflects the teacher's planning and approach to delivering the material, while the students' responses demonstrate their involvement and understanding. Activities refer to the variety and relevance of learning activities, and methods of assessing the suitability of the techniques used. These four dimensions are interrelated and are important indicators in creating a meaningful and quality learning process.

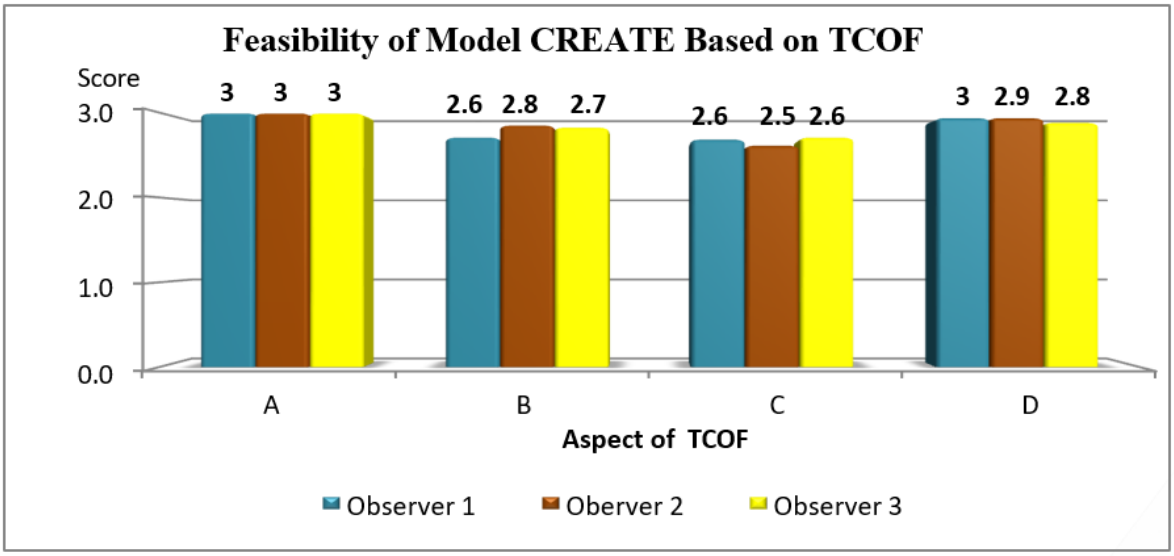


**Figure 1**. Comprehensive Description of TCOF Assessment Results

**Figure 1** shows that the results of observations on the feasibility of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry in building students' multiple creativity show the consistency of positive assessments from the three observers. Observer 1 and Observer 3 gave a TCOF score in the range of 2.6 to 3.0, which was categorized as "good". This determination is targeted at the categorization referred to by Al-Abdali & Al-Balushi (Wahyu, et al, 2020) with a score category of 3 (good), 2 (medium), and 1 (low). This assessment reflects that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is able to facilitate learning that encourages students' creativity as a whole, both in terms of teaching strategies, student responses, activities carried out, and methods used. Students are seen to be active in exploring ideas, showing flexibility in thinking, and being able to develop ideas in an original and structured manner.

Meanwhile, Observer 2 also uses references from Al-Abdali & Al-Balushi (2016). Based on the score range of 2.5 to 3.0 given, it can be concluded that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is considered to be in the "good" category according to the standard. This assessment strengthens the findings of two other observers, that the learning approach using the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is effective in fostering five indicators of creativity according to Williams: fluency, flexibility, originality, elaboration, and evaluation. Students not only generate a lot of ideas, but are also able to critically assess and develop those ideas critically and innovatively.

Overall, the three observers agreed that the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is feasible to be used as a learning strategy to build students' multiple creativity. The active involvement of students in the learning process, divergent thinking skills, and the quality of the resulting products show that this model is able to create a learning environment that supports the optimal development of creative potential. These findings provide a solid foundation for the development of creativity-based learning models at various levels of education, especially in the context of 21st century learning that demands innovation and creative problem-solving.

### Results of Student Multiple Creativity Assessment

**Figure 2** shows the results of the students' multiple creativity assessment based on the Williams Creativity Indicator, providing a comprehensive picture of the creative thinking skills possessed by students. This assessment includes five main aspects (Wahyu et al., 2018): fluency (fluency in producing ideas), flexibility (the ability to think from various points of view), originality (the uniqueness of the ideas produced), elaboration (the development of ideas in detail), and evaluation (the ability to assess and choose the best ideas). Through the analysis of these five indicators, teachers can understand students' creative potential more deeply, as well as design learning strategies that encourage exploration, innovation, and creative problem-solving in various academic and real-life contexts.

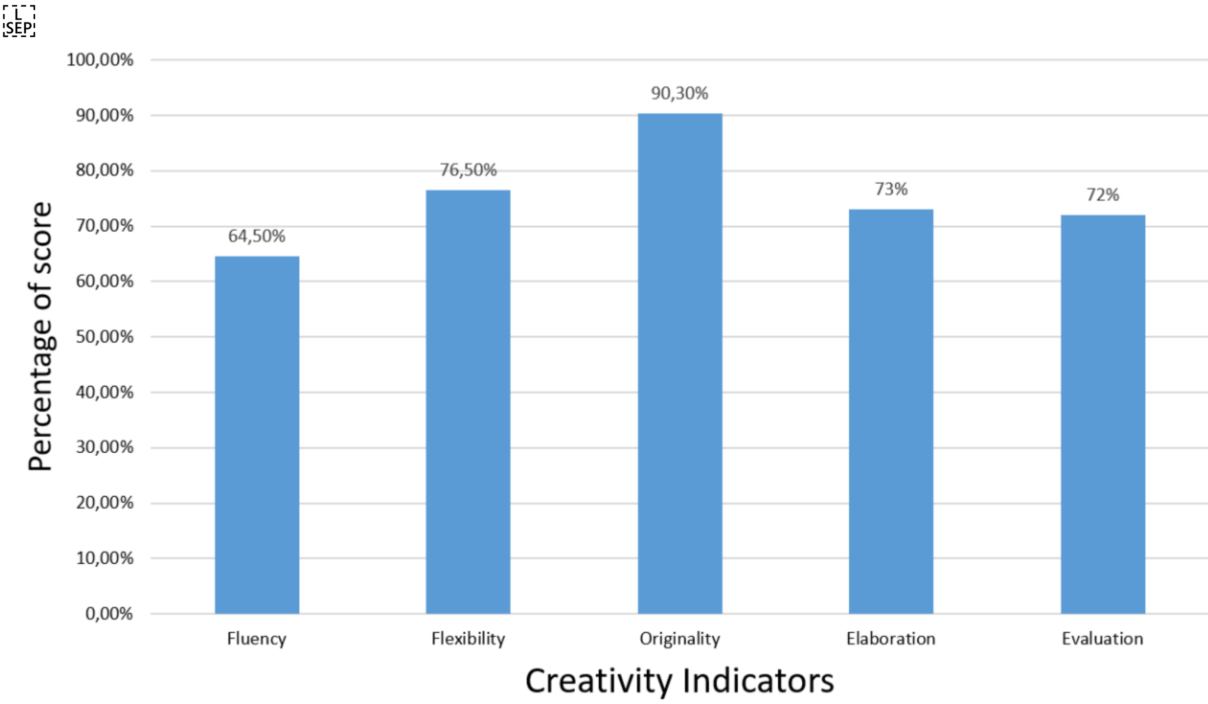


**Figure 2.** Comprehensive description of Multiple Creativity Assessment Results for Students

### Integration of DL-AI-ESD in Green Chemistry in Model C-R-E-A-T-E

Photos of high school students' activities when making eco-friendly hand-soaps made from natural materials are tangible evidence of the integration of Education for Sustainable Development (ESD) in green chemistry learning. Through the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry, students are invited to think critically, creatively, and collaboratively in designing products that are not only safe for the environment, but also relevant to sustainability issues. Collaboration-based learning is more effective than working individually (Verawati et al., 2020). This collaboration-based activity process encourages a deep understanding of the principles of green chemistry while forming a character of caring for the environment. This visual documentation captures students' spirit of innovation and real action in responding to global challenges through transformative and contextual learning.


**Figure 3.** Portrait of Student Activities During the Implementation of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry

As seen in **Figure 3**, all students are actively involved in completing project assignments, showing high enthusiasm and collaboration. They discuss, experiment, and pour out creative ideas independently and in groups. This activity is clear evidence that students' multiple creativity develops while following the learning steps of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry. Each student shows the ability to fluency in generating ideas, flexibility in responding to challenges, and originality and elaboration in designing solutions. Their involvement reflects the success of the Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry in creating a learning environment that encourages innovation, reflection, and creative decision-making.

## CONCLUSION

The conclusion of this study shows that the implementation Model C-R-E-A-T-E based on DL-AI-ESD in Green Chemistry is effective in increasing the plurality creativity of high school students. Based on four research questions, it was found that the need for ESD learning is very high, the model designed is able to support the exploration of creative ideas, and its effectiveness is proven statistically and qualitatively. The revision and validation process through the Design-based Research approach results in adaptive and sustainable learning designs. This model not only improves the understanding of concepts, but also shapes students' environmental awareness and innovative thinking skills.

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