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Validity of the 5C Learning Model (Connecting, Confrontation, Collaboration, Clarification, Confirmation) Based on Virtual Laboratory to Enhance Students' Relational

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ABSTRACT

This study seeks to test the validity of the 5C learning model (Connecting, Confrontation, Collaboration, Clarification, Confirmation) based on a virtual laboratory in the Physical Chemistry II lecture. The 5C learning model was developed to address the challenges of teaching abstract and complex concepts, such as reaction kinetics, which require students to possess relational understanding and deep conceptual thinking skills. This study employed a research and development approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), focusing on the design and development stages. Model validation was performed using the expert judgment of chemistry experts and instructional design experts, who assessed content feasibility, syntax structure, and alignment with modern learning principles. The validation results showed that the learning model possessed very high content and construct validity, with an average score above 90%. The model's validity was supported by theoretical foundations from constructivism (Bruner, Vygotsky). Piaget 's cognitive development theory and Ausubel's theory of meaningful learning were integratively represented in the 5C model's learning syntax. The model's syntax was proven to be logical, systematic, and relevant to the characteristics of the Physical Chemistry II course, and it supported the achievement of graduate learning outcomes (CPL), particularly in strengthening relational understanding. Therefore, the 5C learning model based on virtual laboratory is feasible to be implemented as an innovative responsive approach to chemistry learning in the digital age.

Keywords: model validity, 5C learning model, virtual laboratory, physical chemistry, relational understanding

INTRODUCTION

In the era of digital transformation and the industrial revolution 4.0, science learning is required to be more adaptive to technological advances, especially in the context of higher education. One of the challenges faced by lecturers and students in the Physical Chemistry II course is the difficulty in developing an abstract, procedural, and relational conceptual understanding. Students often experience misconceptions, especially in linking concepts to their application in experiments or real problems.

Relational understanding includes the ability to carry out procedures and the ability to explain the reasons behind those procedures, identify logical errors, and transfer knowledge to new contexts. Therefore, the learning model developed must harmoniously integrate cognitive, affective, and psychomotor aspects. One approach that can potentially address these needs is the 5C learning model (Connecting, Confrontation, Collaboration, Clarification, Confirmation). The 5C model is based on constructivist theory, which emphasizes that knowledge is actively constructed by students through social interaction and meaningful learning experiences. The theoretical foundation of this model is further strengthened by Piaget's cognitive development theory, which emphasizes the importance of cognitive conflict in learning, and Ausubel's theory of meaningful learning, which highlights the role of prior knowledge (schemata) and interconnections between concepts in forming deep understanding.

In addition, implementing virtual laboratories offers a relevant pedagogical solution amidst limitations in physical facilities and the growing need for flexible learning. Virtual labs provide simulation-based experimental experiences and allow students to explore chemical concepts in an interactive, safe, and controlled manner. When combined with the 5C learning syntax, virtual laboratories can serve as an effective medium for reinforcing problem-based, Investigative, and collaborative learning. Researchers must conduct a validity assessment before widely implementing this model in the learning process. The model's validity includes content validity and construct validity, which experts assess. The validation process is essential to ensure that the developed model is relevant, logically structured, and capable of systematically supporting the achievement of graduate learning outcomes (CPL).

Based on the description, this study aims to test the validity of the 5C learning model based on virtual laboratories in the Physical Chemistry II course. Using the ADDIE model development approach, this study focuses on the design and development stages, and examines the validation results provided by subject matter experts and instructional design experts. The findings are expected to contribute to developing innovative learning models that are contextual, valid, and applicable in improving students' relational understanding.

LITERATURE REVIEW

The validity of learning models is a crucial aspect of instructional design development. According to Dick and Carey (2001), model validity includes the suitability between components of the model and the instructional objectives to be achieved, as well as the logical relationship between model's syntax. A valid learning model must be based on a strong learning theory, possess a systematic syntax, and be contextual to the teaching material and the characteristics of the students. Sison et al. (2024) developed a virtual laboratory using the ADDIE approach and conducted a validity test on its design. The results indicated that content and construct validity are in the category of "Very Valid", based on the assessment from subject matter experts and instructional design experts. This study emphasizes the importance of the experts' involvement in assessing the suitability between a model's syntax and its intended learning objectives.

The 5C Model (Connecting, Confrontation, Collaboration, Clarification, Confirmation) is designed to gradually and reflectively build conceptual understanding. The syntax of this model supports constructivism-based learning, where learners actively construct meaning through exploration, discussion, clarification, and reflection. The constructivist theory underlying this model aligns with Piaget's view of cognitive development and Vygotsky's view of the importance of social interaction in the Zone of Proximal Development (ZPD).

Studies by Bazie et al. (2024) examined the impact of virtual laboratories on chemistry students' learning outcomes. Their findings indicate that virtual labs designed based on the principles of modern learning theories (constructivism, inquiry-based learning) can significantly enhance students' academic achievement. This supports virtual laboratories' technical and pedagogical validity in chemistry learning. Furthermore, Rahayu and Yuliana (2025) emphasized that implementing constructivist theory in elementary education is important in improving conceptual understanding through contextual and meaningful learning experiences. This strengthens the relevance of the 5C model's syntax, particularly the Connecting and Confrontation stages, which serve to activate prior knowledge (schemata) and foster productive cognitive conflicts.

Yulis and Oktariani (2024) developed e-learning-based chemistry content using the ADDIE approach and conducted a validity test. The validation results showed that the developed instructional design was considered highly appropriate for the needs of analytical chemistry learning. This aligns with the approach used to develop the structured, virtual laboratory-based 5C model.

These studies confirm that learning models designed with a strong theoretical basis and validated by experts tend to demonstrate high reliability in learning practices. In the context of physical chemistry education, applying the 5C model based on virtual laboratories provides an opportunity to significantly improve students' relational understanding, as it integrates exploratory, collaborative, and reflective learning experiences.

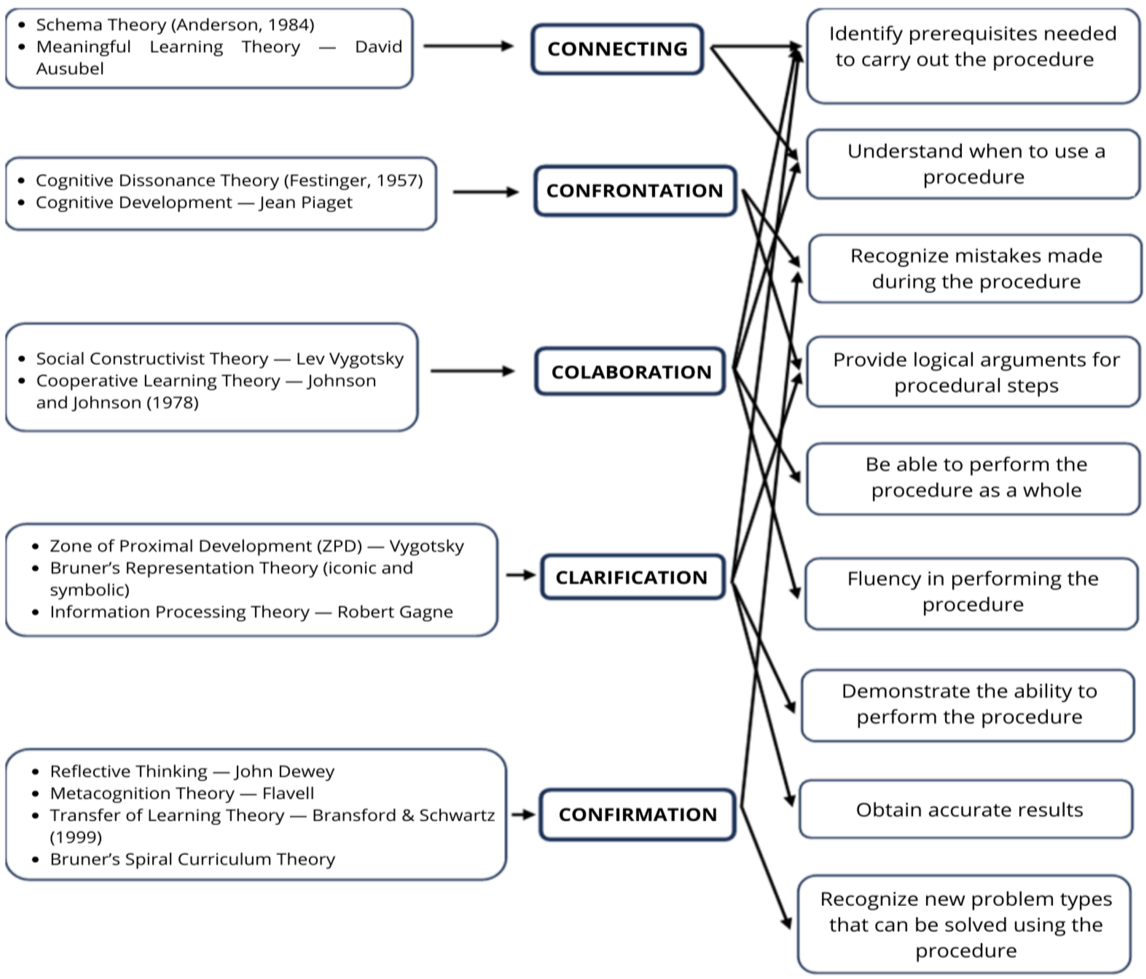

Figure 1. 5C Learning Model

MATERIALS & METHODS

This research design uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as an instructional design framework to develop and test the validity of the 5C learning model based on virtual laboratories. The focus is directed at the first two stages of the five main stages in the ADDIE model, namely Design and Development, which strategically function as the foundation for building the structure and content of the learning model to be validated. At the design stage, a systematic design of the learning components is carried out, starting with identifying graduate learning outcomes (CPL) in the Physical Chemistry II course, especially those related to the relational understanding aspect. Learning objectives are formulated based on these competencies, and the 5C learning syntax is developed. Connecting, Confrontation, Collaboration, Clarification, and Confirmation are then developed logically and theoretically aligned. During this stage, virtual laboratory media are also designed using software such as Crocodile Chemistry, which serves as an interactive platform for conceptual exploration. Additionally, validation instruments in the form of expert assessment sheets are prepared to support the evaluation process in the next stage.

The initial design in the development stage is implemented as a complete learning model prototype, including a user guide and teaching tools such as teaching materials and LKPD, all aligned with the 5C syntax. The validity of the model is tested through expert judgment, a validation technique that involves assessment by experts with specific competencies. In this case, two groups of experts are involved: chemical material experts, who assess the relevance of the content, the depth of the material, and the integration of concepts with CPL; and instructional design experts, who assess the feasibility of the model structure, syntactic coherence, and suitability with modern learning design principles.

The validation process is carried out using an instrument based on a 4-point Likert scale, including content and construct validity indicators. The validation data are analyzed quantitatively by calculating the average score for each assessed aspect. This study uses the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as an instructional design framework to develop and test the validity of the 5C learning model based on virtual laboratories. The research specifically focuses on the first two stages of the five main stages in the ADDIE model, namely Design and Development, which serve as the foundation for constructing the structure and content of the model to be validated. At the design stage, the learning components are systematically developed, starting with identifying graduate learning outcomes (CPL) in the Physical Chemistry II course, especially related to relational understanding. Learning objectives are formulated based on these competencies, and the 5C learning syntax (Connecting, Confrontation, Collaboration, Clarification, and Confirmation) is developed to logically and theoretically align. During this stage, virtual laboratory media are also designed using software such as Crocodile Chemistry, serving as an interactive platform for conceptual exploration. Additionally, validation instruments in the form of expert assessment sheets are prepared to support the evaluation process in the next stage.

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RESULT AND DISCUSSION

The validity of the learning model serves as a fundamental aspect of instructional development research. It reflects the extent to which the designed model is following its theoretical foundation and the practical needs encountered in the field. In the context of abstract and conceptual physical chemistry learning, there is a need for a model that is not only theoretical but also applicable, structured, and technology-based. The 5C learning model (Connecting, Confrontation, Collaboration, Clarification, Confirmation), which incorporates virtual laboratories, emerges as a response to these challenges.

The construct validity of the learning model is reflected in its consistent and integrated internal structure, where each component from learning objectives, syntax, media, lecturer roles, to evaluation methods is logically arranged and mutually supportive, forming a coherent and systematic learning flow. Meanwhile, the content validity of the 5C learning model is demonstrated through an assessment of its alignment with relevant learning theories and its applicability to real-world needs, especially in the context of physical chemistry learning, which demands high levels of conceptual and representational skills.

Content validity assesses the extent to which the model's components reflect the principles of learning theory and the intended instructional objectives. This study analyzed content validity based on five main indicators: supporting theory, rationality of objectives, learning syntax, learning environment, and clarity of model components. The results of expert assessments for these five aspects are presented in Table 1 below.

Table 1. Results Evaluation Content Validity of the 5C Model

No	Rated aspect	Average Rating (%)	Category Validity
1	Supporting Theory	98%	Very Valid
2	Objective Rationality	97%	Very Valid
3	Syntax Learning	97%	Very Valid
4	Environment Study	92%	Very Valid
5	Model Validity	98%	Very Valid

This research indicates that the 5C learning model, which was designed based on constructivist principles and technology-enhanced learning, demonstrates strong validity. The model's learning syntax explicitly reflects key principles, such as schema activation, meaning elaboration, and collaborative reflection, at the core of meaningful learning in the 21st century. The high scores in "supporting theory" and "clarity of model components" further highlight the model has strong theoretical justification and a clear and coherent instructional structure.

This is consistent with the findings of Jung et al. (2022), who emphasize the importance of schema-based learning design in supporting the development of relational understanding, especially in digital learning environments that demand flexibility, learner independence, and integrative connections between concepts. Construct validity refers to the internal consistency and logical integration among the model's components, including objectives, syntax, media, lecturer roles, and evaluation strategies.

In the context of the 5C learning model based on virtual laboratories, construct validity is assessed by examining the alignment between learning objectives, the learning syntax or steps, media used, the instructional role of lecturers, and the designed evaluation system. This aspect is critical, as the effectiveness of a model depends not only on the strength of its components but also on the coherence and integration among them. The 100% agreement from experts on the consistency of the 5C learning model structure shows that the designed syntax is logically and systematically arranged, with each stage reinforcing the others. Each phase, from Connecting to Confirmation, functions not as a separate element but as an integral part of a coherent learning flow that gradually guides students in building a deep and relational cognitive structure. This coherence is essential in chemistry learning c, which demands a solid understanding of the connection between macroscopic, microscopic, and symbolic representation. The integration of these three levels is a core competence in modern chemistry (Gkitzia et al., 2020). The findings of Gilbert and Treagust (2009) also the integration of these three levels is a core need to integrate all three representational levels in teaching chemistry. The flexibility to move between these levels is considered the essence of relational understanding.

The integration between the elements of the model, ranging from objectives, syntax, and media to the role of the lecturer and evaluation, demonstrates that this model is valid in its design and ready to be implemented effectively in the classroom. This finding is reinforced by Weinrich and Talanquer (2016), who emphasized that representational coherence is key in helping students construct stable, consistent, and meaningful conceptual understanding in chemistry. Therefore, the construct validity of the 5C model is not only structural, but also supports the development of a reflective, integrative, and problem-oriented learning process on transformation understanding.

This model connects the theoretical framework with concrete implementation through a structured and contextual learning syntax within a digital environment. The application of virtual laboratory technology not only addresses the limitations of physical facilities but also creates a flexible, engaging, and self-directed learning environment. Research by Makransky et al. (2019) supports this approach, showing that the use of virtual laboratories significantly increases students' emotional and conceptual engagement, ultimately strengthening the effectiveness of learning abstract and complex materials. Therefore, the 5C model is theoretically relevant and responsive to the demands of contemporary pedagogy and educational technology.

CONCLUSION

The validation results obtained from experts show that the 5C learning model based on virtual laboratory has a very high level of content and construct validity. Therefore, the 5C model is considered highly suitable for implementation as an innovative learning strategy that can significantly enhance students' relational understanding in technology-based physical chemistry learning.

Declaration by Authors

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