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Introduction of the Concept of Repercentation (ConRe) in the Design of Physics Learning Media Representations

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Abstract

Contemporary developments in physics learning media have predominantly emphasized technology elements instead of content analysis and conceptual representation. This study was designed to investigate how Concept Representation (ConRe) can assist prospective physics teacher in creating more comprehensive and pedagogically sound physics content representations. The study was carried out over three years involving two cohorts of physics students. Data were gathered from two digital learning media production projects, observations of the learning process, iterative feedback sessions, and analysis of idea representation artifacts. The findings show that in absence of guidance students typically adopt representations in a simplistic form. Moreover, the implementation of the ConRe framework, students demonstrated considerable enhancements in examining material depth, discern essential conceptual structures, and choose varied representations.

Introduction

The growth and development of learning media has undergone significant expansion in the last ten years (Zahroni, 2022). The growth is motivated by the necessity to offer an increasing number of readily accessible educational resources that can overcome the constraints of traditional teaching materials found in schools (Alam, 2021; Mullens & Hoffman, 2023). In numerous educational research, the restricted access to textbooks, the deficiency of teaching aids, and the absence of varied learning materials have compelled teachers, researchers, and practicion to produce various kinds of digital media to enhance the learning process (Saraswati et al., 2020). The digital transition is further enhanced by the growing support of educational technology, which allows teachers to provide more engaging and adaptable learning experiences.

The rapid improvement in artificial intelligence (AI) have enhanced the capabilities of learning media, especially in delivering more personalized, adaptable, and data-informed educational experiences (Hariyanto et al., 2025; Iman et al., 2024). The incorporation of AI in educational settings enables students to engage with material more comprehensively, receive expedited feedback, and access knowledge representations that were once challenging to convey through conventional media (Almuhanna, 2025). In the realm of physics learning, characterized by abstract events, mathematical models, and intricate visualizations, the capacity of AI to enhance conceptual comprehension is becoming increasingly important.

However, technological advancements do not automatically resolve the essential issues in physics education, especially concerning the delivery of conceptual, accurate, and pedagogical material. Teachers are going to be essential in guaranteeing that the learning resources utilized by students accurately and significantly embody physics topics (Redish & Kuo, 2015). Unfortunately, numerous studies indicate that the design of learning media frequently prioritizes technical elements, such as visual aesthetics, interactive features, or software advancements, while content-related factors, especially the depth and coherence of physics material, are comparatively overlooked (Da Silva, 2020; Hariyanto et al., 2025; Iman et al., 2024; Shahjad & Mustafa, 2025; Zahroni, 2022). Many of the learning resources generated prioritize technological sophistication over the representation and comprehension of physics topics by students.

The inequality between technical advancement and the quality of content representation highlights the importance for a framework to assist teachers and prospective teachers in developing effective content-based learning media. A promising method is Concept Representation (ConRe). ConRe offers a systematic framework for the identification, analysis, and organization of physics concepts in a structured format. This method underscores that the material's presentation must illustrate the internal relationships among concepts, the employed mode of representation (verbal, mathematical, diagrammatic, graphical), and a logical sequence that facilitates the development of students' comprehension. In this way, ConRe utilizes as both a technological instrument and a pedagogical framework, ensuring that each learning media development substantially facilitates conceptual learning rather than only enhancing visual aesthetics.

The ConRe in the development of physics learning media is an strategic way to combine the requirement for technological advancement with the delivery of high-quality information. This approach enables prospective teachers to create media focusing on physics principles in the design, ensuring that each visual, narrative, and interactive component enhances comprehension. Hence, ConRe significantly enhances the representational literacy of physics teachers in the digital age, while promoting the development of learning resources that are both technologically advanced and conceptually sound.

Concept Reprecentation (ConRe)

In the Technological Pedagogical and Content Knowledge (TPACK) framework, prospective teachers were exposed to Content Representation (CoRe) as a tool to delineate how material content is comprehended, taught, and conveyed to students (Hervas & Medina, 2022; Mulyani & Hermayani, 2021; Sundman & Röj-Lindberg, 2023). CoRe highlights the interplay between content, pedagogical approaches, and comprehension of students' learning challenges, empowering teachers to provide more reflective and targeted instruction (Nasution et al., 2017; Tseng et al., 2022). While CoRe establishes a crucial basis for linking content and pedagogy, this framework has not specifically delineated how physics concepts should to be represented in the design of contemporary, rapidly growing digital learning media.

In this situation, ConRe has evolved as a novel approach that emphasizes the systematic, structured, and representational presentation of physics concepts. ConRe was conceived under the premise that the quality of learning media is influenced not solely by its technological advancement, but also by the precision and profundity of its conceptual representation. To construct effective physics learning media, prospective prospective teachers must possess a comprehensive understanding of the topic, including its conceptual structure, interrelations among concepts, and the contextual framework of the phenomena to be explored (Banda & Nzabahimana, 2021; Fan, 2015). This comprehension facilitates the development of multimedia teaching materials that are both instructive and facilitate students in constructing significant knowledge.

The ConRe technique relies on multiple analytical factors that must be taken into account when formulating representations of physics concepts. At first, prospective teachers must have an extensive understanding of the physics material to be delivered, encompassing definitions of fundamental concepts, interconnections among concepts, essential physical circumstances, and potential extensions or applications of these concepts across diverse settings. A profound comprehension of the material is essential to prevent misunderstandings and guarantee that the representations offered are precise and thorough (Larkin, 2014). This is the main requirement because a wrong understanding, even with sophisticated learning media, will still result in errors in students' understanding or misconception (Feltovich et al., 2001).

Secondly, learning media designers have to understand the global learning objectives anticipated from physics education. These global goals pertain to essential abilities to be cultivated through learning, including scientific reasoning, numeric literacy, comprehension of physical laws, and the capacity to relate concepts to real-world situations. By comprehending the global learning orientation, aspiring educators can customize concept representations to align with the overarching learning trajectory (Banda & Nzabahimana, 2021).

Third, ConRe requires a comprehensive comprehension of the material delivery workflow. Physics is a distinctly hierarchical field, where certain notions serve as requirements for comprehending others. Therefore, prospective teachers must discern the logical progression of content presentation to ensure that their designed media promote sequential, organized learning that does not perplex students (Kind & Chan, 2019).

Fourth, comprehending the unique competency acquisition of the topic under examination is a crucial aspect of ConRe. At this juncture, prospective teachers have to evaluate the curricular standards and the competency benchmarks to be attained through the subject matter. These competencies may encompass analytical, procedural, experimental, and representational skills. In fact, the conceptual representation crafted in the media might facilitate the attainment of the needed competencies (Gates, 2017).

Finally, ConRe underscores the significance of comprehending the diverse forms of representations that can be utilized in physics learning materials. Representations may manifest as mathematical symbols, diagrams, animations, graphs, narratives of phenomena, interactive simulations, or a combination thereof (Gates, 2017). By selecting and integrating suitable representations, prospective teachers can assist students in connecting the diverse conceptual perspectives essential for a deep understanding of physics.

The ConRe approach demonstrates significant theoretical validity when situated within the framework of scientific education research and theory. ConRe, be it verbal, mathematical, graphical, diagrammatic, or dynamic visualization has been acknowledged as fundamental to the science learning process, especially in physics, where numerous phenomena are abstract and not directly observable. In the context of multirepresentational learning, varied representations assist students in developing a thorough understanding where multiple representations can enhance one another, rectify any mistakes, and promote comprehension of the interconnections among concepts (Berthold & Renkl, 2009; Haque, 2024). Thus, ConRe provides an analytical instrument for learning media designers to identify the most suitable representations and their optimal integration to enhance learning efficacy.

Moreover, ConRe can be seen as a distinct offshoot of the concept of TPACK. TPACK highlights the importance for teachers to transform content knowledge into an accessible format for students (Niess, 2012). This is about choosing suitable representations, instructional methods, and presentation orders. ConRe provides prospective teachers with focused guide on the representation and design of physics subject in learning media, emphasizing the development of representational and conceptual elements rather than simply picking teaching methodologies.

ConRe is applicable to facilitating the control of students' cognitive load within the framework of cognitive theory. Due to the frequent use of mathematical symbols and abstract representations in physics, inadequate design can lead to an unnecessary cognitive burden (Moore et al., 2020; Sinclair et al., 2004) ConRe employs systematic representation analysis to create media that minimizes extraneous cognitive load and enhances germane load, hence optimizing information processing and concept internalization.

Additionally, ConRe's standpoint corresponds with Dual Coding Theory, which posits that information is more effective when conveyed through both verbal and visual means (Hodes, 1994). In the realm of physics teaching materials, this implies that narrative descriptions, mathematical symbols, diagrams, and visualizations must be cohesively integrated to enhance understanding rather than fragment knowledge. ConRe advocates for the incorporation of representations to enhance memory, comprehension, and information transmission.

Besides that, ConRe enhances students' representational literacy as the capacity to navigate, compare, and convert among several representations of an idea. This literacy is crucial in physics as students frequently encounter scenarios requiring them to interpret graphs, formulate equations, illustrate force diagrams, or articulate events verbally. Media designed according to ConRe can promote students' development of representational fluency, leading to a diversified and profound comprehension.

The background of contemporary educational technologies further underscores ConRe's significance. The utilization of interactive media, simulations, and AI-driven platforms is becoming more common. however, in the absence of a definitive conceptual framework, these technologies risk becoming merely "ornamental" as an aesthetic pictures devoid of substantive accuracy and depth of substance. ConRe underscores that technology serves as a tool rather than a goal. Technology integration is significant only when it enhances conceptual representation, preserves scientific integrity, and facilitates the learning process. Consequently, ConRe provides an equilibrium between technology advancement and educational excellence.

With this theoretical base, ConRe establishes itself as a strong and appropriate framework for the construction of physics learning media. It enriches and elaborates on the content and pedagogical dimensions previously covered by TPACK, while integrating cognitive theory and representation theory within the framework of contemporary learning media in science education. The application of ConRe allows prospective teachers and learning media developers to construct media designs that are visually attractive, conceptually coherent, and pedagogically sound significantly enhancing the quality of

physics teaching in the digital era. Table 1 below serves as a foundational tool for conducting the necessary concept analysis prior to the comprehensive creation of ConRe as a component of learning media.

Table 1
ConRe Table of Representation (Example in Force Concept)

Sub-Concept	Representations that will be provided in learning media*									
	Verbal / Text	**Math**	**Graph**	**Diagram**	**Figure**	**Tabel**	**Animation**	**Simulation**	**Video**	**Hand On**
Free Body Diagram	Stimulus is given regarding the position of the hanging bucket and the object on the inclined plane.	-	-	The diagram presented is a free-style diagram of the problem presented.	For this case, the image presented relates to an inclined plane and a hanging bucket.	-	-	Presents a simulation of the change in force vectors on a free force diagram when the object's position is moved.	-	-
Newton's Second Law	Presented case stories regarding Newton's Second Law	$\mathbf{F} = m.\,\mathbf{a}$	The proportionality graph of **F** and **a** is presented.	The diagram presented is a free-style diagram of the problem presented.	For this case, the image presented relates to an inclined plane and a hanging bucket.	A summary table is presented regarding the force and direction of the force in general cases.	-	Presents a simulation of the change in force vectors on a free force diagram when the object's position is moved.		Handouts are provided for students to conduct simple investigations of Newton's Second Law on inclined planes using the provided simulations.
....										

** The form of representation presented depends heavily on the student's learning needs and the developer's ability to present it. The more representations that can be explored, the more opportunities students will have to understand physics from a variety of perspectives.*

Put Table 1 here

Research Methods

This study used an exploratory methodology to investigate the development of competences among student physics teachers to create physics content presentations utilizing digital learning media (Reiter, 2017). The study primarily aims to find transformations in the quality of physics concept representation before and after the introduction of the Concept Representation (ConRe) framework for content analysis. The exploratory technique was selected as this study seeks to thoroughly understand the phenomena of competency development within a natural and continuous setting.

The study was executed in two primary phases. Initially, students were instructed to create physics learning resources that were "as interactive as possible" without receiving specific directives on content analysis. Students were granted the autonomy to decide the format, design, and media references utilized in the development of their works. The initial products were subsequently shown to the class, allowing researchers to make preliminary observations on how students depicted physics principles in their generated medium. At that point, researchers offered comments centered on content elements and presented the ConRe framework as a mechanism for evaluating concept representation to enhance the depth and coherence of physics content in digital learning media.

Repeated introductions and mentoring on the utilization of ConRe were conducted throughout the course, involving two cohorts of students from the physics education program: seventh-semester students enrolled in the Physics E-learning course and third-semester students in the ICT Literacy and Physics Learning Media course. All participating students had fulfilled required courses encompassing fundamental physics concepts and elements of physics pedagogy. The observation method included three consecutive academic years and involved three distinct student cohorts, enabling researchers to acquire a longitudinal perspective on the evolution of representational competencies.

Data was gathered through the assessment of two primary projects concerning the advancement of digital learning media. In the initial assignment, students were tasked with creating a learning media design that encompassed curriculum analysis, the development of learning media concepts, and an examination of the physics information to be delivered. This design functioned as a preliminary assessment of students' proficiency in mapping conceptual frameworks, assessing the material's depth, and establishing a coherent logical representation. In the second project, students executed the concept into a digital learning media product (Bowen, 2009). The finished output was evaluated to see the degree to which students could combine a comprehensive depiction of physics ideas in alignment with the ConRe principles.

This study primarily examines the content analysis and conceptual representation issues that arise in the design of digital learning media, despite its dynamic and multifaceted characteristics. Innovation models and alterations in product forms are not subject to review. This study highlights the quality of conceptual representation as a key indication of student competency growth in physics education.

Findings

Student Analysis of Conceptual Reprecentation

Preliminary research results suggest that when students are afforded unrestricted autonomy in creating digital learning media without specific direction, most prefer to replicate the presentation of content available in textbooks or online resources. The selected idea representations are typically generic, unstructured, and exhibit no effort to adjust or customize the information to meet learning requirements. This pattern suggests that, despite enhanced access to educational resources, student capacity for content analysis remains constrained. This finding aligns with literature emphasizing that the shortcomings of representation in conventional learning resources are frequently the subject of research (Bouchée et al., 2022; De Westelinck et al., 2005; Poldrack, 2021). Despite this, prospective teacher keep on within utilizing these sources as their principal reference without examining the quality of their representation.

This circumstance indicates that the fundamental issue resides not in the scarcity of instructional materials, but in the ability of prospective teachers to critically evaluate, interpret, and reconstruct conceptual frameworks (Bouchée et al., 2022). Hence, the implementation of the ConRe framework is an essential measure to enhance students' representational awareness in the creation of learning media.

Qualitative data analysis from the original and subsequent projects revealed various patterns in students' comprehension of idea representation. Initially, students exhibited a propensity to arbitrarily choose representational forms, disregarding pedagogical urgency or conceptual significance. They generally presumed that more representational forms, such as pictures, animations, simulations, and narratives enhanced the efficacy of the learning media. Further investigation indicated that the disproportionate selection of representations heightened students' cognitive load and distorted conceptual continuity (Moore et al., 2020). The failure to prioritize representational concepts signifies that students are in the preliminary phase of cultivating representational literacy, which encompasses the capacity to choose and connect representations according with explicit instructional objectives.

Secondly, students sometimes develop ConRes superficially, lacking thorough content examination. In several instances, essential ConRe components, like links among ideas, logical sequences of facts, or clarification of transitions between representations, are formulated in a simplistic manner and lack extensive conceptual analysis. When these designs are implemented in digital learning media, students encounter frustration due to the chosen representations lacking sufficient conceptual foundations. This pattern reveals a disparity between representational design and technical execution, indicating that technological proficiency alone does not ensure the integrity of concept representation.

Third, students determined that ConRe should to serve as an analytical framework for preliminary planning. In practice, numerous students disclosed that they needed to modify the structure of ConRe upon facing technical and conceptual constraints during the learning media production process. This iterative change embodies a debate between conceptual design and technical realities, a prevalent dynamic in technology-driven learning design. This result illustrates that ConRe serves not just as a planning tool but also as a reflecting device that compels students to examine their understanding of physics topics and their representations.

These patterns suggest that students are shifting from a technology-centric approach to media design to one that emphasizes content and conceptual representation (Hsu et al., 2023; Lekena-Bayaga & Bayaga, 2025). The application of ConRe illustrates how and in which conceptual representations should to be designed, chosen, and organized effectively. These findings highlight the necessity for continuous mentoring to facilitate students' development of sufficient pedagogical sensitivity and representational expertise in creating physics educational media.

Best Practice Analysis ConRe

This is crucial to highlight that the ConRe analysis process functions not merely as a technical procedure in the development of learning media, but also as an epistemic process that influences how students comprehend, organize, and pedagogically structure physics concepts. The findings of this study suggest that students require a clear analytical framework to ensure that the process of producing conceptual representations is systematic rather than random or entirely instinctive. Therefore, numerous best practices can be established based on the empirical results of this qualitative exploratory research.

At the begining, students must meticulously examine the Learning Outcomes and Learning Objectives. This preliminary phase suggests students to cultivate a robust comprehension of the objectives they must achieve, rather than only what they should articulate as prospective teachers. This analysis necessitates students to designate fundamental competencies, ascertain levels of cognitive complexity, and assess the alignment between educational objectives and the prospective representations to be employed (Baihaqi et al., 2021). In successful practice, students not only peruse the learning outcomes but also engage in discourse regarding the context of the material, rendering this process an interpretive activity that embodies the essence of qualitative research such as attempting to comprehend the significance and purpose of curriculum documents in relation to the instructional experiences to be developed.

Furthermore, student must construct a logically organized Learning Objective Flow (LOF) (Riswakhyuningsih, 2022). Research findings reveal that students who fail to develop an LOF tend to formulate ConRes randomly and exhibit a lack of coherence amongst representations. In this context, formulating an LOF beyond basic administrative function, it is a conceptual process that establishes the sequence of ideas, prerequisite links among concepts, and the convergence of content and representational strategies. A LOF acts as a pedagogical framework that guarantees conceptual representations align with students' cognitive development, in its absence, representations risk becoming ornamental, non-educational, or potentially deceptive (Kallia & Cutts, 2023). Students should revalidate their LOFs by assessing the coherence of concepts and their appropriateness for the selected learning model.

Additionally, students must perform comprehensive theoretical analyses of physics content utilizing authorized sources, such as university-level physics textbooks (Wulandari et al., 2018). This study indicates that a primary source of students' challenges in building ConRe is the insufficient examination of the physics concepts themselves. Representations cannot be educational if student conceptual comprehension remains superficial (Furwati et al., 2017). Thus, best practices underscore the necessity for students to engage in conceptual unpacking, which involves deconstructing a parent concept into its sub-concepts, principles, restrictions, circumstances, assumptions, and mathematical relationships. This means that students do not merely replicate information from textbooks or other resources. In fact, they actively recreate the scientific significance of a topic within the educational setting. The reconstruction process is fundamental to creating genuine and significant conceptual representations.

Finally, students must ultimately develop Core and ConRe representations in a stimulating way, employing an iterative and reflective methodology in the building process. This method involves that students initially develop CoRe, which include essential definitions, interrelations among variables, or fundamental phenomena, prior to incorporating supplementary representations such as images, graphs, simulations, analogies, or mathematical expressions (Nasution et al., 2017). Students are prompted to consistently evaluate the quality of each representation. Its efficacy in fostering conceptual comprehension, its capacity to expand views, and its alignment with scientific principles and educational aims. This study determined that the optimal approach at this step is to implement iterative revisions, incorporating comments from peers or instructors, so transforming the ConRe development process into a collaborative and reflective effort rather than merely a final output.

These activities argue that ConRe analysis is not solely a technical procedure, but an educational activity that enhances students' pedagogical topic knowledge. By commencing with learning outcomes, formulating a cohesive LOF, enhancing the analysis of physics information, and creating engaging representations, students can generate more sophisticated, organized, and pedagogically robust ConRe. The findings suggest that the quality of learning media is predominantly influenced by the quality of the initial analysis in ConRe development, necessitating increased focus on this process within the pre-service teacher education program.

Conclussion and Discussion

The results of this exploratory study demonstrate that ConRe functions as an effective analytical framework to improve prospective physics teachers ability to create more comprehensive and pedagogical presentations of physics content. In the preliminary phases, students typically create learning media grounded in restricted representations, primarily verbal and mathematical, neglecting the epistemic framework of physics concepts and the variety of representational forms essential for enhancing students' conceptual comprehension. This trend corresponds with the results of numerous prior studies indicating that student teachers frequently imitate representational patterns from textbooks or online resources without sufficient conceptual analysis, leading to a learning process that is merely information transmission (Airey & Linder, 2009; Çepni & Şahin, 2012).

The implementation of ConRe illustrated that interventions based on representational planning may considerably change students' perceptions of content design. Through scaffolding and ongoing feedback, students exhibited advancement in analytical, reflective, and representational awareness in their thinking. This transformation was evident in their selection, integration, and interpretation of visual, mathematical, conceptual, and phenomenological representations in a more balanced and significant way. This aligns with the literature on representational competence, which proposes that a robust comprehension of scientific concepts necessitates the capacity to integrate various modes of representation (Disessa, 2004; Kozma & Russell, 2005b, 2005a).

From an educational perspective, these findings confirm that the development of TPACK is intrinsically linked to the capacity to create representations that align with the content's nature and the learning characteristics of students. The ConRe model seems to serve as a means of internalizing fundamental elements of TPACK, specifically in the areas of 'knowledge of instructional representations' and 'knowledge of content and students,' as suggested by Shulman (1986) and subsequently elaborated in the TPACK framework (Koehler & Mishra, 2009). By compelling students to contemplate the complex structure of concepts, the interconnections among representations, and the educational objectives to be fulfilled, ConRe fosters a pedagogical sensitivity that was previously lacking in the initial design.

This study further substantiates prior research indicating that prospective teachers frequently require a framework to assess and enhance suitable scientific representations (Eilam & Gilbert, 2014; Treagust et al., 2018). In this context, ConRe not only offers technical guidance for the presentation of physics content but also advocates for a paradigm shift from merely “creating engaging media” to “designing pedagogically sound representations of concepts.”

In General, this study enhances the discourse on the significance of representational scaffolding in physics education and prospective teacher. ConRe exhibits significant potential as a resource for cultivating content analysis skills and serves as a link between physics content expertise and conceptually focused digital learning media design methodologies. Future research necessitates a comprehensive investigation into the systematic integration of ConRe within teacher education curricula and its enduring effects on representational competence.

Declarations

Data Availability Statement

The data supporting the findings of this study consist of student-generated learning products collected during regular classroom activities. Due to ethical and privacy considerations, the data are not publicly available. Anonymized data may be made available from the corresponding author upon reasonable request.

Ethical Considerations

This study involved human participants (undergraduate students) whose academic work was analyzed retrospectively. The data were derived from regular classroom activities conducted as part of the officially approved course curriculum, and no additional intervention was introduced for research purposes. Ethical approval for this study was obtained from Universitas Pendidikan Indonesia, and the research was conducted in accordance with institutional guidelines for minimal-risk research involving human participants. All data were fully anonymized prior to analysis, and no personally identifiable information is reported in this manuscript.

Consent to Participate

The requirement for written informed consent was waived by Universitas Pendidikan Indonesia because the study involved a retrospective analysis of anonymized student academic work collected during routine instructional activities and posed minimal risk to participants.

Consent to publish

The manuscript does not contain any individual person's identifiable data in any form. All data analyzed in this study were anonymized prior to analysis. As the study involved a retrospective analysis of anonymized student academic work collected during routine instructional activities and posed minimal risk, the requirement for written informed consent to publish was waived by Universitas Pendidikan Indonesia in accordance with institutional guidelines.

Conflicts of Interest

The authors declare no conflicts of interest.

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