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Conceptual Understanding: A Concept Analysis

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Abstract

The term conceptual understanding was analyzed to determine how educators can help students attain understanding in a concept based curriculum. The investigator sought to establish what salient dimensions and conditions supported conceptual understanding. A dimensional analysis of the term conceptual understanding was employed through a review of the literature in mathematics, science, psychology, and nursing education. The salient dimensions of conceptual understanding were identified as: factual and procedural knowledge, connections, transfer, and metacognition. The supporting properties included: meaningful learning activities, memorization, and misconceptions. The results substantiate conceptual understanding as a process. When this process is utilized by nurse educators, students may better connect and organize knowledge aiding in the knowledge transfer that occurs between theory and practice.

Keywords

Dimensional Analysis, Education, Conceptual Understanding

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The term conceptual understanding was analyzed to determine how educators can help students attain understanding in a concept based curriculum. The investigator sought to establish what salient dimensions and conditions supported conceptual understanding. A dimensional analysis of the term conceptual understanding was employed through a review of the literature in mathematics, science, psychology, and nursing education. The salient dimensions of conceptual understanding were identified as: factual and procedural knowledge, connections, transfer, and metacognition. The supporting properties included: meaningful learning activities, memorization, and misconceptions. The results substantiate conceptual understanding as a process. When this process is utilized by nurse educators, students may better connect and organize knowledge aiding in the knowledge transfer that occurs between theory and practice. *Keywords: Dimensional Analysis, Education, Conceptual Understanding*

Nursing curricula has been moving away from a content focus to a more conceptual foundation. Teaching students to understand concepts as opposed to memorizing content is necessary in the current health care environment. Rapid advances in medical knowledge and technology have demonstrated that it is impossible to teach students everything they will need to know to practice nursing (Dalley, Candela, Benzel-Lindley, 2008; Giddens, 2007; Giddens & Brady, 2007; Hardin & Richardson, 2012; Ironside, 2004, 2005). Therefore, it is necessary that we equip students with the tools for conceptual understanding.

Many nursing students will tell you they are not good at mathematics. However, it is extremely important that nurses are able to correctly perform and determine the accuracy of medication calculations. I was a nurse who thought that I would never excel in mathematics. However, as a novice teacher I was asked to teach a medication calculation course. This course was different from the one I had in my own undergraduate education. Rather than memorizing a formula, as I had been taught, students were encouraged to solve medication calculations in any way that made sense to them. A fire was ignited as mathematics suddenly made sense to me and I was able to problem solve through most calculations.

Conceptual understanding was a term mentioned regularly in preparing to teach medication calculations to undergraduate nursing students. The term was cited in nursing literature (Kelly & Colby, 2003; Wright, 2007) related to teaching medication calculations however, no definition or description of what it meant to have conceptual understanding or to teach for conceptual understanding was evident. The intention of this concept analysis was to begin to uncover what it means to have conceptual understanding. The foundation of this concept analysis was utilized in building a grounded theory of conceptual understanding in nursing students learning medication calculations (Mills, 2012). The application of the process of conceptual understanding goes beyond one topic in a curriculum and has potential for influencing many areas of education.

Dimensional Analysis as a Qualitative Inquiry

There are various methods available for concept analysis. Walker and Avant (2005) described a procedure for concept analysis that included identifying antecedents, defining empirical referents, and distinguishing cases such as model and invented cases. This procedure was not consistent with an abstract concept such as conceptual understanding. The method of dimensional analysis (Caron & Bowers, 2000) seemed more consistent with the investigator's belief that constructivist pedagogy is best when teaching for conceptual understanding. The foundation of dimensional analysis in pragmatism and symbolic interaction was congruent with constructivism. Discovery of the social construction of the concept further allowed the investigator to examine conceptual understanding through other's contexts and perspectives. Dimensional analysis was developed by Schatzman (1991) as "a methodological approach to the grounding of theory in qualitative research" (p. 303). For these reasons a qualitative approach to a concept analysis of conceptual understanding was deemed appropriate.

Data Sources

In dimensional analysis the definition of a term can vary depending upon the contexts and perspectives in which it is used. Caron and Bowers (2000) stated "The outcome of dimensional analysis is intended to provide a better understanding of systematically generated differences in meanings and uses of the concept" (p. 297). Therefore, reference materials were sourced in areas in which the term conceptual understanding was found. Data was located using an electronic literature search of the Cumulative Index of Nursing and Allied Health (CINAHL), Psychological Literature (PsycINFO), and Education Literature (ERIC) databases from 1980 to 2014 using the keyword *conceptual understanding*. There were 1,500 articles in the education literature, 1,326 articles in the psychology literature and 110 in the nursing and allied health literature. Twenty-three of the allied health articles were nursing specific. Articles were limited to English language. All of the nursing articles and the first one hundred psychology and education articles were reviewed for use of the term conceptual understanding. Articles were reviewed in more depth if conceptual understanding was a primary focus. In addition to the search, five articles on medication calculation that investigated or discussed conceptual understanding were also included as teaching medication calculations was the exemplar concept.

Data Collection and Analysis

Dimensional analysis commenced with an examination of the explicit and implicit definitions of the concept in question (Caron & Bowers, 2000). Explicitly, there were no dictionary definitions of the term *conceptual understanding*. A definition of the term *concept* was, "Based on or relating to ideas or concepts" (Merriam Webster online dictionary). A definition of the term *understanding* related to comprehension was "the power to make experience intelligible by applying concepts and categories" (Merriam Webster Online Dictionary). In the mathematics education literature, the term *conceptual understanding* was more established than in other contexts. Kilpatrick, Swafford, and Findell (2001) defined conceptual understanding as "an integrated and functional grasp of mathematical ideas, students with conceptual understanding know more than isolated facts and methods" (p. 118).

The nursing education literature included teaching for conceptual understanding but did not clearly define the concept. The term was found in research on knowledge development, curriculum, and medication dosage calculations. Schultz and Meleis (1988) discussed conceptual knowledge as a type of knowledge specific to the discipline of nursing. Conceptual learning was also discussed in relation to achieving conceptual understanding. Additional literature exploring the need for transforming the undergraduate nursing curriculum from a content based entity to one that emphasizes conceptual learning and understanding followed (Dalley et al., 2008; Giddens, 2007; Giddens & Brady, 2007; Hardin & Richardson, 2012; Ironside, 2004, 2005).

Analysis of literature pertaining to conceptual understanding began with mathematics and science education. The educational psychology articles were read next followed by the literature in nursing education. Articles were read for themes related to teaching for conceptual understanding. Special attention was paid to how the concept was used. This is consistent with an interactionist perspective, Caron and Bowers (2000) described the importance of the inclusion of how concepts are used across contexts. Common perspectives and uses of the term were noted in the early stages of the analysis of data. As understanding progressed common dimensions were organized across contexts and their relationships were made more explicit. A process of how one might come to attain conceptual understanding began to emerge with salient dimensions identified.

Trustworthiness and Rigor

According to Caron and Bowers (2000) it is important to begin a dimensional analysis by outlining what the investigator believes to be true about the concept. I began this investigation believing that memorization of facts was the opposite of conceptual understanding. By making this perspective explicit, I was able to compare this belief with what was evident in the literature. I also believed that meaningful learning strategies were an important part of how a student attained conceptual understanding. By analyzing perspectives of conceptual understanding across contexts I was able to identify "the complexity and contextuality of the concept" across disciplines (Caron & Bowers, 2000, p. 299). Finally, by identifying a process of conceptual understanding and sharing it with mentors and colleagues for validity and feedback I was able to refine the process and use it to further build a grounded theory (Mills, 2012).

Organization of Results

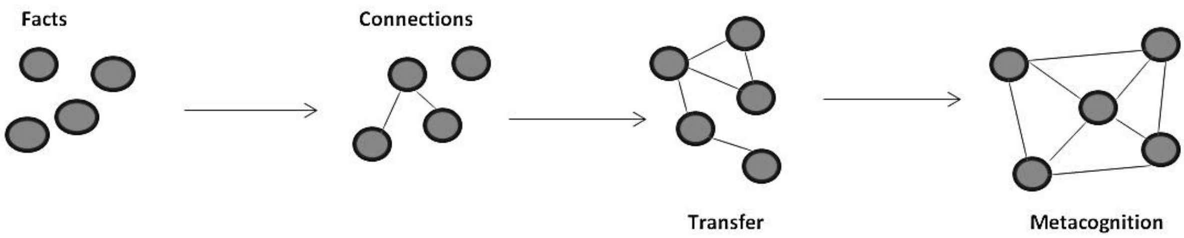
The results of this concept analysis are organized around the dimensions of conceptual understanding. Salient dimensions are central to the meaning of conceptual understanding and represent aspects of knowledge formation that are required to attain conceptual understanding of a subject. The conditions that may be seen as beneficial or challenging to the attainment of conceptual understanding are also included. The relationships between the salient dimensions and the conditions delineate the process of how conceptual understanding may be attained and the consequences of this attainment.

Results

Salient Dimensions

Four salient dimensions of conceptual understanding emerged from the dimensional analysis. The salient dimensions were: factual and procedural knowledge, making connections, knowledge transfer, and metacognition. Each of these dimensions is described below and outlined in a dimensional matrix (Figure 1).

Figure 1 Dimensional Matrix of Conceptual Understanding



Factual and procedural knowledge. Results related to conceptual understanding were found predominantly in the mathematics and science literature. Initially, there were studies that described the dichotomy in the perspectives from which math and science are taught. Debate in mathematics and science education as to the importance of conceptual understanding versus rote learning and memorization was prevalent (Devlin, 2007; Kilpatrick et al., 2001; Rittle Johnson & Star, 2007). Kilpatrick et al. (2001) defined conceptual understanding in mathematics as "an integrated and functional grasp of mathematical ideas, students with conceptual understanding know more than isolated facts and methods" (p. 118). An iterative model of mathematical learning has been described by Gilmore and Bryant (2008) as a synthesis of these two perspectives. Students should be able to select and perform mathematical procedures based on an understanding of when and why these procedures are appropriate. Integrating both procedural and conceptual knowledge can lead to conceptual understanding (Rittle-Johnson & Star, 2007). Adding an emphasis on the fluency, efficiency, and precision of factual and procedural knowledge was also described as necessary in order to begin to grasp conceptual understanding (Devlin, 2007; Rittle-Johnson & Star, 2007; Ross & Wilson 2012).

Many nursing students are taught to memorize mathematical formula for calculating drug dosages. Memorizing procedures without understanding is consistent with curricular approaches that focus on content rather than conceptual understanding. Teaching only facts and procedures can be problematic, especially for students who are weak in mathematics. Nursing students who are unable to perform basic mathematical skills are given a *recipe approach* with mathematical formula to follow for medication calculations. Studies have shown that this is an ineffective approach because elements of the calculation become *meaningless* (Kelly & Colby, 2003; Wright, 2005). Nurse educators should consider that sole reliance on the procedural aspects of teaching medication calculations is ineffective without conceptual understanding.

Thus the starting point in the process of conceptual understanding was the attainment of factual or procedural knowledge. It was evident from the mathematics literature that the student must have a sound foundation of factual and procedural knowledge in order for conceptual understanding to take place (Ross & Wilson, 2012). Declarative knowledge was a condition for, but did not guarantee, conceptual understanding. Knowing pieces of factual information forms the foundation for understanding, but facts and procedures cannot remain isolated.

Connections. Across contexts, and especially in the mathematics and science literature, the importance of connecting knowledge so that facts and procedures do not remain isolated was reinforced. Integrating new concepts and promoting conceptual learning through concept maps, reflection, and making connections, fosters deep learning and enhanced conceptual understanding (Cassata, Himangshu, & Iuli, 2004; Giddens, 2007; Ritchart, Turner, & Hadar, 2009). A mental image of the importance of connections was illustrated beautifully by Heibert and Carpenter (Grouws, 1992). They describe the process of understanding like a spider web with the "junctures of the web as pieces of information and the threads as connections or relationships" they go on to state "All of the nodes are ultimately connected, making it possible to travel between them by following established connections, some nodes are connected more centrally than others" (p. 69).

Assisting nursing students with making connections between what they already know and medication dosage calculations may help the student achieve conceptual understanding. In promoting teaching medication dosage calculations from a constructivist perspective, Kelly and Colby (2003) highlighted the importance of making connections and transferring knowledge. In learning medication dosage calculations this can be done by helping students to see the relationship between the calculations and previously learned knowledge in middle school or high school mathematics and basic chemistry concepts. Additionally, helping students to connect the principles of ratio and proportion or drug reconstitution to everyday tasks reinforces learning.

As the student builds up factual and procedural knowledge they begin to connect the facts. The more knowledge is connected to other knowledge and the stronger these connections become, the more likely a subject is to be understood. Retrieving information is easier and more efficient when information is well connected as opposed to remaining as isolated facts and procedures.

Knowledge transfer. Knowledge transfer is particularly important in the practice disciplines of teaching and nursing. In a study of empowering health care workers Miers, Coles, Girot, and Wilkinson (2005) discuss transfer between theory and practice. They state "Conceptual knowledge facilitates transfer and students can learn to transfer conceptual knowledge to their interpersonal practice" (p. 183). Connecting and transferring knowledge was also highlighted in the education literature (Franz, Hopper, & Kristonis, 2007; Sigler & Saam, 2006). This literature highlighted the importance of conceptual understanding in moving back and forth between theory and practice in transferring learning.

Literature in nursing education described incorporating concepts throughout the curriculum that could help students to connect and transfer knowledge from theory into practice (Giddens & Brady, 2007; Harrison & Gibbons, 2013; Ironside, 2005; Kelly & Colby 2003; Randall, Tate, & Lougheed, 2007; Wright 2006, 2007, 2008). Transferring knowledge of medication dosage calculations to nursing care is a critical component of safe nursing practice. In teaching medication dosage calculations this transfer goes beyond rote memorization of formula. Students who do not have conceptual understanding of the differences between volume, dose, and concentration will have no way of knowing if the volume they are going to administer to a patient makes sense. When students have not been able to transfer knowledge from mathematics they lack number sense. This can result in entering numbers into a formula in the wrong order. This could result in giving the patient 2 tablets instead of the half of a tablet that should be given.

Although knowledge transfer and making connections seem similar, they are two different dimensions of conceptual understanding. It would be impossible to transfer knowledge without making connections. However, knowledge transfer also encompasses taking isolated facts or knowledge and utilizing it in a new way or with a previously unknown topic. Transferring previously known facts to a new topic helps the learner to reinforce connections and think in a different way.

Metacognition. Literature in the area of metacognition was frequently described in the mathematics and science literature from the perspective of novice learning (Chen & Bradshaw, 2007; Mestre, 2002; Spier-Dance, Mayer-Smith, Dance, & Khan, 2005). Mestre (2002) described the knowledge of the novice as "amorphously organized" in relation to the expert's knowledge which is highly organized within a hierarchical structure (p. 11). In the nursing education literature Kelly and Colby (2003) also described the novice learner's focus on surface learning as opposed to making connections and transferring the knowledge needed for metacognition and conceptual understanding.

Giddens and Brady (2007) identified conceptual learning as a process by which students learned how to organize information into logical mental structures, thus enhancing conceptual understanding by strengthening the thought processes. As the learner organizes information they are able to find the information more readily and use it appropriately. In learning medication dosage calculations, the goal of achieving conceptual understanding is to support the student as they perform increasingly complex applications. The student is able to do this as they go from understanding the very basics of fluid volume to calculation of intravenous drip rates. As students become more comfortable with these calculations they can move to applying them to calculating fluid maintenance based on body weight. Assisting students with the integration of their medication dosage calculation knowledge can lead to organizing their knowledge in a way that will help them make sense of the information.

Metacognition is the knowledge one has about their thinking and the use of strategies to guide and redirect thinking (Gredler, 2008). Metacognition is about how the student organizes their knowledge. Organizing knowledge into logical structures that are fluid enough to change as knowledge increases is an integral part of the metacognitive process. As metacognition increases so should conceptual understanding.

Conditions

There were three conditions that influenced the salient dimensions to either enhance or inhibit the attainment of conceptual understanding. The influential conditions were: meaningful learning activities, memorization, and misconceptions.

Meaningful learning. The attainment of conceptual understanding was aided by the inclusion of meaningful learning activities. Much of the literature describing how students achieved conceptual understanding included a description of meaningful learning activities that took place in a social and active learning environment. A number of teaching strategies were outlined in the literature including cooperative problem solving, comparing solution methods, concept mapping, case studies, reverse case studies, and analogies (Beyer, 2011; Chen & Bradshaw, 2007; Downing, Kwong, Chan, Lam, & Downing 2009; Giddens & Brady, 2007; Jansen, 2012; Ritchart, Turner, & Hadar, 2009; Rittle-Johnson & Star, 2007; Spier-Dance et al., 2005). Meaningful learning activities helped students to cultivate deep learning and enhanced conceptual understanding.

The conditions that influence the achievement of conceptual understanding apply to the process of learning medication dosage calculations as well. Meaningful learning strategies allow students to apply and make sense of what they are learning. When a student is able to practice the procedure for reconstituting medications they can see first-hand that the amount of diluent added is an important aspect of the concentration of the resulting solution. As students engage in meaningful learning activities they are also able to dispel misconceptions.

Misconceptions. The term misconception refers to an error in student thinking. Ongoing misconceptions interfere with learning and provide a barrier to conceptual understanding by hindering assimilation and accommodation of knowledge (Milligan & Wood, 2010). One of the conditions necessary for conceptual understanding to take place was that misconceptions were corrected or not present. Evaluating misconceptions can be valuable to future learning and conceptual understanding. As van Es and Conroy (2009) stated "mistakes are sites for learning" (p. 87). Learning involves shaping and defining knowledge based on what is already known and the reinterpretation of misconceptions. Refining knowledge by addressing misconceptions helps students to learn and retain knowledge.

In teaching medication calculations, it is very important to help students understand and correct their misconceptions. A common misconception among nursing students relates to the volume of liquids. When a student is unable to visualize what one liter looks like as opposed to one milliliter they are unable to conceive of whether their answer makes sense. You would not want your nurse to bring you five liters of cough syrup instead of the 5 milliliters you were ordered. Identifying and correcting misconceptions assists a student in achieving conceptual understanding.

Memorization. There were findings in the literature that both supported a certain amount of memorization of facts and procedures (Devlin, 2007) and that described memorization as a barrier to understanding (Ironside, 2005; Rittle-Johnson & Star, 2007; Spier-Dance et al., 2005; van Es & Conroy, 2009). Ironside (2005) described the process of memorization as encouraging surface learning and as a prevalent scenario in undergraduate nursing curricula. The focus on memorization can impede the student's ability to think deeply about a subject. Knowing facts is not the same as understanding how they can be of use. However, in learning mathematics some memorization of facts was found to be a necessary starting point for knowledge and the process of conceptual understanding (Ross & Wilson, 2012).

Memorizing a formula is not conducive to understanding the process of calculating medication dosages. Numbers can be easily reversed when putting them into a formula that does not make sense to the student. This could result in a serious medication error. Helping students to realize that by understanding medication dosage calculations they can be successful in mathematics is an important way to bolster confidence. This success is critical if they are to confidently and accurately calculate medication dosages.

Memorizing facts and isolated procedures was assumed to be a deterrent to understanding. However, in this analysis, some memorization was seen as integral to forming the basis of understanding. In mathematics education memorization was described as a necessary first step in the process of conceptual understanding. As students are able to connect, transfer and organize knowledge they rely on memorization less as knowledge builds. The student who is a novice learner is assumed to rely more on surface learning and be less adept at organizing information into the meaningful whole required for conceptual understanding.

Relationships of the Dimensions

The relationship of the dimensions of conceptual understanding has been demonstrated as a flat, linear structure resulting in a *metacognitive* web of understanding (Figure 1). However, in considering the process of conceptual understanding, it is anything but flat. The web can be seen as the foundation for building knowledge through understanding. As in constructivist pedagogy, early conceptual understanding is the framework for previous knowledge to be built upon. It would be as if the flat web structure was to grow in height and width becoming three dimensional. Meaningful learning is integrated into the constructivist perspective and methodologies as a way of connecting and building on students' previous knowledge (Jonassen, 2006). Giddens and Brady (2007) summarized the relationship of the dimensions of conceptual understanding in nursing curriculum stating "Conceptual teaching and learning complement the constructivist paradigm in fostering critical thinking and deep understanding through the connections students make to past learning, their application to multiple contexts and their development of inter-related concepts" (p. 68).

The central perspective of this analysis is that the attainment of conceptual understanding is a process. This was reinforced by Milligan and Wood (2010) who described conceptual understanding as a "provisional destination" rather than being an irrefutable endpoint (p. 498). The view of conceptual understanding as a provisional destination included learning from misconceptions, allowing for the expansion and building of knowledge as an ongoing process. The process of conceptual understanding is strengthened under the condition of meaningful learning. By applying meaningful learning strategies, the consequence was gains in conceptual understanding by "making the material more meaningful, memorable and accessible to the learner" (Spier-Dance et al., 2005, p. 196).

Consequences

The end result of the process of synthesizing factual information that is connected to previous learning in an organized way is that the learner is able to attain conceptual understanding. In an earlier definition of conceptual understanding by Kilpatrick et al. (2001) it was noted that there needs to be an "integrated and functional grasp of mathematical ideas" (p. 118). Devlin (2007) described this as: a realistic goal is that the learner has sufficient understanding to work intelligently and productively with the concepts and to continue to make progress while allowing for future refinement or even correction of the learners concept as understood in the light of further experience (p. 2). This goal is also relevant for nursing education. Conceptual understanding constitutes an important aspect of knowledge development in nursing education that has implications for nursing curriculum. Giddens and Brady (2007) stated "A concept-based curriculum coupled with a conceptual learning approach can prepare nurse graduates who are skilled at conceptual thinking and learning: such skills are necessary to respond to a rapidly changing profession and health care environment" (p. 68).

Discussion

Conceptual understanding is a concept that was previously defined and described in mathematics education (Kilpatrick, 2001). Following years of debate regarding the role of factual fluency and conceptual understanding (Devlin, 2007) a blending of the two viewpoints has been considered (Gilmore & Bryant, 2008). Nursing education is far too content focused and could benefit from an emphasis on conceptual teaching and learning (Giddens & Brady, 2007; Ironside, 2004, 2005). One area in the nursing curriculum that has traditionally focused on memorization of content is the formula driven approach to teaching medication calculations (Kelly & Colby, 2003; Wright, 2005, 2006, 2007).

Aside from mathematics education, conceptual understanding is not defined. Additionally, the dimensions of conceptual understanding have not been explicated in any context and there is no known process for helping students to attain conceptual understanding. This study offers a multi-contextual synthesis of the literature related to the facets of conceptual understanding and the conditions that support its attainment. A process that outlines the formation of conceptual understanding can help educators who desire to help students connect and transfer knowledge in an organized and cognitively deep manner. Each aspect is important independently, but when combined the result of conceptual understanding is that learning goes beyond the sum of the parts. Beginning with a topic in the nursing curriculum, like medication calculations, that relies heavily on mathematics education serves as a good starting point. The maturity of the concept in mathematics education allowed for a foundation of understanding that could be expounded in a different context. The concept of conceptual understanding clearly has applicability in other areas of education.

Generalizability

Dimensional analysis is based on a qualitative approach that grounds the data in what is known across contexts. Analysis of this concept was focused in mathematics, science, and nursing education, however, literature pertaining to social studies, health science and teacher education was also examined. Discovery of the social construction of the concept across contexts lends itself to generalizability within contexts with potential applicability beyond studied contexts. The proposed process of the attainment of conceptual understanding allows for the possibility of testing in other areas of education.

Limitations

This study was limited by the number and scope of relevant literature; philosophical viewpoints of conceptual understanding would add to the breadth of this aspect of knowledge development. The use of English language literature also limits the generalizability of the findings. The majority of the literature is in mathematics and science education, requiring conceptual translation for application in nursing education.

Implications

The implications of this study are that teaching for conceptual understanding of medication calculations is possible and may allow for improved understanding and retention. When learning becomes individually meaningful and is constructed into schemata it will more likely be retained. The implications for undergraduate nursing education are that teaching for conceptual understanding may improve the student's ability to reinforce connections and organize knowledge. Additionally, it can aide in the transfer of knowledge that needs to occur between theoretical concepts and clinical practice. For nursing education conceptual understanding is especially relevant in light of concern about the content focus of curriculum.

The theoretical implications of conceptual understanding include its potential use as a middle range nursing theory. By describing a process of conceptual understanding it is possible to further investigate the use of the concept in nursing education. Additionally, the influential conditions that allow for the attainment of conceptual understanding can add to the growing body of evidence based educational practices.

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