Review Article

Rethinking contextualization in physics education: a perspective from semantic gravity

Abstract

This study examines the applicability of Semantic Gravity (SG), a concept derived from Legitimation Codes Theory, as a tool to enhance contextualization in physics teaching. SG offers a framework for analyzing how educators and students navigate between abstract concepts and concrete applications, addressing one of the persistent challenges in physics education: the gap between theoretical understanding and practical application. The study reveals that implementing SG presents both significant opportunities and considerable challenges. Opportunities include the development of a more profound and transferable understanding of physics concepts, more inclusive teaching practices, and more authentic assessment methods. Challenges encompass teachers' need for a deep understanding of the concept, adaptation of existing curricular materials, and development of rigorous methods to assess their impact. Research suggests integrating SG into teacher training and curriculum design could significantly transform physics teaching. However, further empirical research is required to validate its effectiveness fully in diverse educational contexts.

Keywords: Semantic Gravity, physics teaching, contextualization, teacher training, semantic profiles

Volume 8 Issue 4 - 2024

Guillermo Cutrera
Science Education Department, Facultad Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Buenos Aires, Argentina

Correspondence: Guillermo Cutrera, Science Education Department, Facultad Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Buenos Aires, Argentina, Funes 3350. CP: 7600, Email guillecutrera@gmail.com

Received: October 2, 2024 | **Published:** October 29, 2024

Introduction

Physics teaching faces significant challenges in contemporary education, particularly regarding contextualization and deep conceptual understanding of students. Despite advances in teaching methodologies, many students continue to perceive physics as an abstract discipline connected to their everyday reality.[1] This perception negatively affects students' interest and motivation and hinders their ability to apply physics concepts in real-world contexts.[2]

In response to these challenges, research in physics education has explored various approaches to improve contextualization and conceptual understanding. Among these, Legitimation Codes Theory, and precisely the concept of Semantic Gravity (SG), has emerged as a promising theoretical framework to analyze and improve science teaching practices.[3] SG refers to the degree to which the meaning of a piece of knowledge is tied to its context, providing a conceptual tool to examine how educators can navigate between abstract concepts and concrete applications in physics teaching.

The relevance of SG in physics teaching lies in its potential to address the persistent gap between theoretical understanding and practical application. Recent studies have shown that students often need help to transfer abstract physics knowledge to real-world situations, partly due to a disconnect between the SG of taught concepts and the contexts in which students are expected to apply them.[4] Implementing SG-based strategies can offer a more nuanced approach to contextualization in physics teaching. By manipulating SG, educators can create "semantic profiles" that facilitate movement between abstract concepts and concrete applications, enhancing students' understanding and transferability.[5] This approach not only has the potential to make physics more accessible and relevant to students but can also foster the development of critical thinking and problem-solving skills essential to the discipline.

The crucial role amplifies the importance of addressing these challenges in physics education, which this discipline plays in shaping future scientists and scientifically literate citizens. In an increasingly technological world, understanding and applying physical principles in diverse contexts has become essential for innovation, global problem-solving, and informed decision-making.[6] Therefore, improving the effectiveness of physics teaching through approaches such as the application of SG is a matter of educational improvement and preparation for the challenges of the 21st century.

Despite SG's potential for physics teaching, its practical application in the classroom and its integration into teacher training still need to be explored. Recent research has begun to examine how physics teachers can use SG to structure their lessons and activities. However, a deeper understanding of the specific strategies and challenges associated with its implementation is still needed.[7] In response to this need, the present paper aims to analyze the applicability of Semantic Gravity as a conceptual tool to understand and improve contextualization in physics teaching.

Semantic gravity in educational research

Semantic Gravity (SG), a concept derived from the Legitimation Codes Theory, has emerged as a promising conceptual tool to address persistent challenges in physics teaching. This section examines the application of SG in diverse educational contexts, from science teaching in general to physics in particular, spanning both secondary and higher education.

Georgiou et al.[8] used SG to analyse how physics students navigate between abstract concepts and concrete examples in science teaching. In the context of secondary education, Conana et al.[9] applied SG to examine how physics teachers introduce abstract concepts and relate them to concrete experiences. Mazzitelli et al.[11] studied the semantic dimension in introductory thermodynamics teaching during forced digitalisation, finding significant variations in the semantic profiles used by teachers in this new context. Similarly, Santos and Mortimer[11] analysed the semantic profile of thermochemistry classes for chemistry students, identifying patterns in how teachers navigate between abstract concepts and concrete examples.

These studies are complemented by the work of Martínez et al. (2023) on the use of ICT in the teaching of mechanical physics, which highlights how digital tools can facilitate the modulation of SG in the presentation of physical concepts. Integrating educational technologies is critical in enriching semantic profiles in science teaching.

In higher education, Clarence (2016) applied SG to study how law students learn to "think like lawyers", showing how the ability to move between specific contexts and abstract principles is crucial for professional development. In academic literacy, Kirk[12] used SG to analyse how university students learn to write in their disciplines. The reviewed studies employed a variety of methodologies, with qualitative approaches predominating. Discourse analysis was a standard tool used by Santos and Mortimer[11] to examine chemistry classroom interactions. Other studies, such as Macnaught et al.,[13] used textual analysis to examine how SG manifests in teaching materials. Quantitative studies were less common, but some researchers, such as Blackie,[14] developed instruments to measure SG in teaching practices. Mixed approaches were also observed, such as that of Maton and Chen,[15] who combined qualitative discourse analysis with quantitative measures of SG.

Several studies consistently find that the ability to move fluidly between different levels of SG is associated with better academic performance and a deeper understanding of concepts. For example, Szenes et al.[16] found that students who could effectively navigate concrete examples and abstract principles were more successful in their academic writing tasks.

An emerging trend in research is the use of SG to analyze and improve assessment practices. Steenkamp et al.[17] used SG to examine how high-performing physics students navigate between different levels of abstraction when solving problems. Their findings suggest that the ability to move fluidly between strong and weak SG is associated with better problem-solving performance. Another trend is the application of SG in the analysis of curriculum materials and textbooks. Macnaught et al.[13] demonstrated how these concepts can be applied to the analysis of physics textbooks, revealing patterns in the presentation of knowledge that can influence student understanding. Their study suggests that textbooks that incorporate a variety of semantic profiles may be more effective in promoting a deep understanding of physics concepts.

In the field of teacher education, Langsford & Rusznyak (2024) and Cutrera et al.[19] employed SG to examine how preservice teachers develop their understanding of pedagogical practice. These studies revealed that preservice teachers' ability to manipulate SG in their explanations is crucial to their effectiveness in the classroom, suggesting that SG could be a valuable tool for teacher professional development. In practical terms, SG offers educators a tool to design and evaluate their teaching practices. For example, Maton (2013) suggest that teachers can use semantic profiles to structure their lessons, ensuring an appropriate balance between concrete examples and abstract principles. This could lead to more effective teaching practices facilitating students' deep conceptual understanding.

Furthermore, SG has implications for curriculum design and teacher education. Blackie et al.[14] argue that a well-designed physics curriculum should incorporate a variety of semantic profiles over time, allowing students to develop the ability to navigate between different levels of abstraction fluidly. Regarding teacher education, SG could help student teachers reflect on their practices and develop strategies to make abstract concepts more accessible to students.

Theory of Legitimation Codes and Semantic Gravity

Written by Karl Maton, Legitimation Codes Theory (LCT) has emerged as a robust theoretical framework for analyzing and understanding educational practices in various fields, including physics teaching. This theory provides conceptual tools that examine how knowledge is constructed, transmitted, and assessed in different educational contexts.[20] Among these tools, SG has been highlighted as a particularly relevant concept for addressing challenges in science teaching, especially in physics.

SG refers to the degree to which the meaning of a piece of knowledge is bound to its context. Maton[20] describes a continuum of SG, where at one end is strong SG (SG+), indicating strongly context-dependent meaning, and at the other end is weak SG (SG-), representing more abstract and decontextualized meanings. This concept provides a lens through which one can analyze how teachers and students navigate between the concrete and the abstract in the teaching-learning process.

In physics teaching, SG offers a valuable perspective to address one of the discipline's most persistent challenges: the gap between abstract conceptual understanding and practical application in specific contexts. Georgiou et al.[8] argue that the ability to move fluidly between different levels of SG is crucial for developing a deep understanding of physics. This movement, known as the "semantic wave," involves the ability to connect abstract concepts to concrete examples and vice versa.

The application of SG in physics teaching involves understanding its basic concept and the recognition and use of different semantic profiles. Maton[21] describes several types of semantic profiles, each with its didactic implications and potential to improve students' understanding of physics. Some of these profiles are presented in Figures 1 and 2.

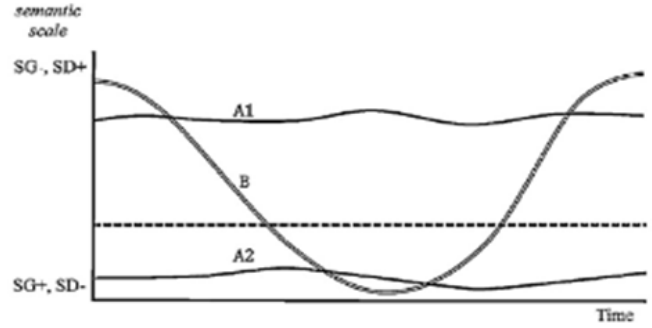

Figure 1 Illustrative profiles and their respective semantic ranges: a high semantic flatline (A1), a low semantic flatline (A2) and a semantic wave(B). Key: SG: semantic gravity; + = stronger; - = weaker. Taken from Maton (2013).

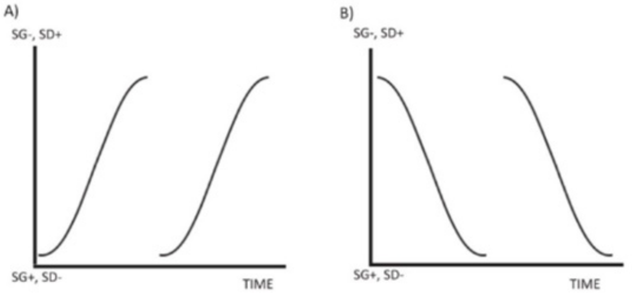

Figure 2 Semantic profiles: (A) upward escalator; (B) downward escalator (C) full semantic wave. Key: SG: semantic gravity; + = stronger; - = weaker. Taken from Maton Carver (2020).

Citation: Cutrera G. Rethinking contextualization in physics education: a perspective from semantic gravity. *Phys Astron Int J.* 2024;8(5):217–223. DOI: 10.15406/paij.2024.08.00351

One of the most common profiles is the "wave profile," which shows a regular alternation between strong (SG+) and weak (SG-) SG. This profile is particularly useful in physics teaching, allowing teachers to move fluidly between concrete examples and abstract principles. For example, when teaching Newton's laws, a teacher might start with a practical demonstration (SG+), then introduce the mathematical formulation (SG-), and finally apply these principles to new situations (SG+).

Another vital profile is the "upper flatline semantic profile," which maintains a weak SG (SG-) over an extended period. This profile can be beneficial for developing a deep understanding of complex physical theories, such as quantum mechanics or relativity. However, Georgiou and Sharma (2022) warn that overuse of this profile can make it difficult to connect to practical applications, a common challenge in teaching advanced physics.

In contrast, the "lower flatline semantic profile" maintains an intense SG (SG+) over an extended period. This profile can be helpful in the initial stages of teaching a new physics concept, allowing students to explore multiple concrete examples before moving to abstraction. However, teachers must raise the SG eventually to promote generalization and abstract thinking.

Maton[22] also describes the "downward escalator semantic profile," which starts with a weak SG and gradually becomes more muscular. This profile can be beneficial in teaching physics and applying abstract theories to concrete situations. For example, when teaching the theory of relativity, a teacher might start with Einstein's equations (SG-) and then show how these apply to observable phenomena such as time dilation in GPS satellites (SG+).

In contrast, the "descending escalator semantic profile" starts with a strong SG and gradually becomes weaker. This profile can be effective in developing theories from empirical observations. In teaching quantum physics, for example, one might start with concrete experiments such as the double slit (SG+) and gradually build up the mathematical formalism of quantum mechanics (SG-).

Applying these semantic profiles in teaching physics has implications for the structure of individual lessons and curriculum design. Blackie et al.[14] argue that a well-designed physics curriculum should incorporate a variety of semantic profiles over time, allowing students to develop the ability to navigate between different levels of abstraction fluidly.

The relevance of SG and semantic profiles extends beyond classroom teaching. Macnaught et al.[13] demonstrated how these concepts can be applied to the analysis of physics textbooks, revealing patterns in the presentation of knowledge that can influence student comprehension. Their study suggests that textbooks that incorporate a variety of semantic profiles may be more effective in promoting a deep understanding of physics concepts.

Semantic waves and profiles in action

Semantic profiles, as an integral part of Legitimation Codes Theory, offer a valuable perspective for analyzing and structuring the teaching of complex concepts in physics. In this section, we present two examples that illustrate how these profiles can manifest in teaching practices. The first case, focusing on stellar evolution and black holes, exemplifies a wave profile, demonstrating how instruction can oscillate between concrete and abstract concepts to facilitate understanding. In contrast, the second case, addressing the theory of general relativity, illustrates a "lower flatline semantic profile," maintaining a strong SG throughout the lesson to make highly abstract concepts accessible. These examples demonstrate the applicability of semantic profiles in teaching advanced physics and offer insights into how educators can structure their lessons to maximize student understanding and engagement.

First example

The following dialogue illustrates how the concepts of waves and semantic profiles manifest in an advanced astrophysics class on stellar evolution and black hole formation. This example demonstrates how a teacher can navigate different SG levels to facilitate an understanding of complex astrophysical concepts.

1. Teacher: Today, we will explore stellar evolution and black hole formation. Can anyone mention something they have observed in the night sky that might relate to this topic?

2. Student 1 (Mia): The different coloured stars we see?

3. Teacher: Excellent observation, Mia. The colours of stars are directly related to their temperature and stage of evolution. Can anyone elaborate on this?

4. Student 2 (Alex): Blue stars are hotter, and red stars are cooler, right?

5. Teacher: Correct, Alex. Wien's law describes the relationship between colour and temperature. Can we express this more formally?

6. Student 3 (Javier): Does it have to do with the electromagnetic spectrum and wavelength?

7. Teacher: Exactly, Javier. Now, we are getting to more fundamental concepts. Wien's law states that λmax = b/T, where λmax is the peak emission wavelength, T is the star's temperature, and b is the Wien constant. How could we relate this to stellar evolution?

8. Student 4 (Sophia): As stars evolve, do they change their temperature and, therefore, their colour?

9. Teacher: Excellent, Sophia. Now, let us think about the final stages of stellar evolution. What happens to very massive stars at the end of their life?

10. Student 5 (Omar): Do they become supernovae?

11. Teacher: Correct, Omar. Moreover, what could be formed after a supernova if the star is massive enough?

12. Student 1 (Mia): A black hole?

13. Teacher: Okay, Mia. Now, can anyone name any unique features of black holes?

14. Student 3 (Javier): The event horizon?

15. Teacher: Excellent! The event horizon is a crucial concept. Mathematically, we can describe it using the Schwarzschild equation: Rs = 2GM/c^2, [where Rs is the Schwarzschild radius (event horizon), G is the gravitational constant, M is the mass of the black hole, and c is the speed of light].

16. Student 2 (Alex): Sorry, but I do not understand how this equation relates to what we could observe in a black hole.

17. Teacher: Good question, Alex. Let us get back to something more concrete. The Event Horizon Telescope recently captured

Citation: Cutrera G. Rethinking contextualization in physics education: a perspective from semantic gravity. *Phys Astron Int J.* 2024;8(5):217‒223.
DOI: 10.15406/paij.2024.08.00351

the first image of a black hole. In that image, we see the black hole's shadow, directly related to its event horizon. The size of this shadow allows us to estimate the black hole's mass using the equation we just saw.

18. Alex: I better understand the connection between theory and observation.

19. Teacher: Good. Let us think about how we could apply these concepts to study the universe's evolution on a large scale. How do you think supermassive black holes at the centre of galaxies influence cosmic structure? [Discursive exchanges between teacher and students continue]

This dialogue illustrates several moves in SG:

1. Begins with concrete examples from everyday life (strong SG): Lines 1-4

2. Moves to more general principles (weakest SG): Lines 5-8

3. Introduces physical laws and concepts (very weak SG): Lines 7-8

4. Applies concepts to astrophysical phenomena (intermediate SG): Lines 9-12

5. Presents highly abstract mathematical expressions (extremely weak SG): Lines 13-15

6. Reapplies these concepts to observable situations when questions arise (strongest SG): Lines 16-18

7. Finally, challenges students to apply these concepts to large-scale cosmological phenomena (semantic undulation between strong and weak SG): Line 19

Second example

The following dialogue illustrates how a semantic profile manifests itself in an advanced physics class on Einstein's theory of general relativity. This example shows how a teacher can maintain a strong SG throughout discursive exchanges, using a lower flatline profile to make highly abstract concepts accessible. This strategy allows students to understand complex principles of relativity through analogies and concrete examples, facilitating the connection between abstract theory and observable phenomena.

1. Teacher: Today, we will explore Einstein's theory of general relativity through everyday examples. Can anyone mention a situation in which they have experienced the passage of time differently?

2. Student 1 (Ana): When I am bored in class, time seems to pass more slowly.

3. Teacher: [class laughter] Excellent example, Ana! Although it is a subjective perception, it helps us think about how time can "feel" different. Anyone else?

4. Student 2 (Carlos): I have heard that astronauts on the International Space Station age slightly slower than we do on Earth.

5. Teacher: Okay, Carlos. That is a real-life example of time dilation. How do you think this relates to gravity?

6. Student 3 (Elena): Is it because they are farther away from Earth and there is less gravity?

7. Teacher: Yes, Elena. Gravity plays a crucial role. Let us imagine we have two identical clocks, one on Earth and one on the Space Station. What would happen to them?

8. Student 4 (David): The clock on the Space Station would go faster, right?

9. Teacher: Right, David. Now, let us think about how this affects GPS satellites. Does anyone know why engineers must consider relativity for GPS to work correctly?

10. Student 1 (Ana): Is it because satellites are in orbit and time passes differently there?

11. Teacher: Exactly, Ana. If this effect were not corrected, errors in location would quickly accumulate. Now, let us imagine that we are near a black hole. What do you think the experience of time would be like there?

12. Student 2 (Carlos): I have seen in movies that time passes much slower near a black hole.

13. Teacher: Good point, Carlos. Although movies sometimes exaggerate, the basic idea is correct. From our perspective, time would slow down enormously near the event horizon of a black hole.

14. Student 3 (Elena): Teacher, how does this affect our understanding of the universe?

15. Teacher: General relativity helps us understand phenomena such as the universe's expansion, galaxies' formation, and even wormholes' possible existence. Consider how light from distant stars bends around massive objects, creating gravitational lenses.

16. Student 4 (David): Is it like space is a stretched sheet, and heavy objects bend it?

17. Teacher: That is a good analogy, David. We could experiment using a stretchy sheet and different objects to represent celestial bodies in class. How about we try it? [Discursive exchanges between teacher and students continue]

This dialogue illustrates a lower flat line profile, maintaining a solid SG (SG+) throughout the conversation. The movements in the SG are:

1. Starts with concrete examples and everyday experiences (strong SG): Lines 1-4

2. Keep the discussion in terms of observable examples and analogies (strong SG): Lines 5-13

3. Introduces broader concepts but still linked to observable phenomena (moderately strong SG): Lines 14-15

4. Returns to using concrete analogies and proposes a practical experiment (strong SG): Lines 16-17

The examples in this paper section illustrate two semantic profiles in teaching advanced physics. The case of black holes shows a wave profile oscillating between everyday observations and abstract concepts such as the event horizon. In contrast, the example of general relativity presents a lower flat line profile, maintaining a strong SG through analogies and concrete examples. Both cases demonstrate how conscious manipulation of SG can be adapted to different topics, facilitating the connection between the familiar and the theoretical and making inherently abstract concepts accessible. This provides educators with flexible tools to address the complexity of advanced physics.

Citation: Cutrera G. Rethinking contextualization in physics education: a perspective from semantic gravity. *Phys Astron Int J.* 2024;8(5):217‒223.
DOI: 10.15406/paij.2024.08.00351

Some implications for teacher training

Incorporating SG as a conceptual tool in physics teaching has profound implications for both preservice and in-service teacher education. These implications range from reflection on pedagogical practices to developing specific skills to manipulate SG in the classroom. Training teachers capable of effectively using SG requires a multifaceted approach that integrates theory, practice, and reflection.

First, teacher education programs must introduce the concept of SG and its relevance to physics teaching. Georgiou et al.[8] argue that understanding SG can help teachers design more effective learning experiences, facilitating the transition between abstract concepts and concrete applications. This understanding needs to go beyond mere theory; preservice teachers need opportunities to apply SG in simulated and real-life teaching situations.

Teacher reflection plays a crucial role in this process. Maton and Chen[22] suggest that SG can be a metacognitive tool for teachers to analyze and improve their teaching practices. By reflecting on how levels of SG vary in their explanations and activities, teachers can identify opportunities to improve the clarity and accessibility of their lessons. This reflection can be structured through teaching journals, peer discussions or mentor feedback sessions.

Developing skills to manipulate SG in the classroom is another crucial aspect of teacher training. This involves not only understanding the concept theoretically but also being able to apply it in a fluent and contextualized way. Georgiou and Sharma[7] suggest that active learning approaches, which can be interpreted as manipulating SG, can improve students' conceptual understanding of physics. Based on this, we propose that teacher training programmes include practical activities where prospective teachers design and execute lessons with different SG profiles. These activities may include:

1. Analysis of existing teaching materials from an SG perspective.

2. Designing teaching sequences that deliberately incorporate variations in SG.

3. Practicing explanation techniques that facilitate the construction of semantic waves between abstract concepts and concrete examples.

Effective implementation of SG in physics teaching also requires teachers to develop metacognitive skills. Georgiou and Sharma[7] suggest that teachers should be able to critically reflect on their teaching practices from an SG perspective. This involves analyzing how levels of abstraction vary in their explanations, identifying critical moments for constructing semantic waves and evaluating the effectiveness of their strategies in facilitating student understanding.

To foster these metacognitive skills, teacher education programs can incorporate activities such as:

1. Analyzing physics lecture videos and identifying and discussing changes in SG.

2. Maintaining reflective journals where teachers document and analyze their experiences with applying SG.

3. Participating in communities of practice where teachers can share and discuss strategies for manipulating SG in different physics topics.

The relevance of teacher reflection in the context of SG extends beyond individual improvement. As Blackie et al.[14] point out, collective reflection on teaching practices can lead to significant changes at the institutional level. The authors argue that SG can serve as a common language for physics teachers to discuss and improve their pedagogical practices, facilitating interdepartmental collaboration and the development of coherent approaches to teaching physics across the institution.

A crucial aspect of teacher training about SG is developing the ability to design and use "semantic profiles" in physics teaching. Macnaught et al.[13] define semantic profiles as visual representations of how SG varies throughout a teaching sequence. These profiles can help teachers plan and assess their lessons, ensuring an appropriate balance between abstract concepts and concrete applications. Training in the use of semantic profiles could include:

1. Practical workshops where teachers design semantic profiles for different physics topics.

2. Analyze semantic profiles from successful lessons and discuss how to replicate these strategies.

3. Practice adapting semantic profiles for different student levels and educational contexts.

Another important aspect of teacher training is the development of skills in assessing student understanding from the SG perspective. Georgiou and Sharma[5] propose that teachers should be able to design assessments that measure students' knowledge and their ability to navigate between different levels of SG. This could involve:

1. Training in designing questions that require students to apply physics concepts in various contexts.

2. Development of assessment rubrics that explicitly consider students' ability to move between the abstract and the concrete.

3. Practice interpreting student responses from an SG perspective to inform future instruction.

Teacher training should emphasize the importance of metacognition in using SG. Georgiou et al. (2022) suggest that teachers should be able to critically reflect on their own teaching practices from an SG perspective. This involves being aware of how they are using SG in their lessons and adjusting their strategies in real-time in response to student needs.

Finally, it is essential to recognize that the effective implementation of SG in physics teaching requires a change in the broader educational culture. As Blackie et al.[14] point out, this involves not only individual teacher training but also the development of communities of practice where educators can share experiences, collectively reflect on their practices, and collaborate in developing new SG-based strategies.

Challenges and opportunities in the implementation of SG in physics teaching

Implementing SG in physics teaching presents a complex landscape of challenges and opportunities that deserve careful consideration. One of the main challenges in implementing SG is the need for teachers to understand the concept deeply. Georgiou and Sharma[7] point out that many physics teachers, although experts in their field, may not be familiar with the principles of Legitimation Codes Theory and SG. This knowledge gap can hinder the practical application of SG in the classroom. To address this challenge, it is critical to develop teacher training programs that not only introduce the theoretical concepts of SG but also provide practical examples

Citation: Cutrera G. Rethinking contextualization in physics education: a perspective from semantic gravity. *Phys Astron Int J*. 2024;8(5):217–223. DOI: 10.15406/paij.2024.08.00351

and opportunities for teachers to experiment with its application in specific physics teaching contexts.

Furthermore, adapting existing curricular materials represents another considerable challenge. Traditional physics textbooks and educational resources often need to be designed with SG in mind, as Hazari, Sonnert, Sadler, and Shanahan[6] indicate. This implies the need for a substantial revision of teaching materials to ensure that they facilitate movement between different levels of abstraction and contextualization. This process can be both costly and time-consuming.

Assessing and measuring the impact of SG on student learning also presents difficulties. Developing rigorous methods to quantify this effect remains a developing area of research, requiring new assessment approaches that can capture students' knowledge and ability to navigate different abstraction levels. Evaluating the effectiveness of SG-based strategies represents another major challenge. While theory suggests significant potential benefits, it is crucial to develop rigorous methods to measure the impact of these strategies on student learning. Steenkamp, Rootman-le Grange, and Müller-Nedebock[17] have begun to address this challenge by analyzing introductory physics assessments using SG as a framework, but further research is needed to develop standardized assessment tools that can effectively capture the benefits of this approach.

However, in the face of these challenges, the opportunities offered by implementing SG are equally significant and promising. One of the main opportunities is the possibility of developing a deeper and more transferable understanding of physics concepts. By facilitating movement between different levels of abstraction, SG can help students build stronger connections between theory and practice. Georgiou and Sharma[7] suggest that SG-based strategies can improve students' ability to apply physics concepts in new contexts, thus addressing one of the most persistent problems in physics education.

Furthermore, SG offers the possibility of developing more inclusive teaching practices. Kelly et al.[4] argue that explicit attention to SG can help educators design learning experiences accessible to students with diverse backgrounds and learning styles, thereby contributing to more equitable physics education.

The implementation of SG also offers opportunities for innovation in assessment. As Georgiou and Sharma[7] point out in their study of active learning in thermodynamics, assessments designed with SG can provide a more complete and nuanced picture of student learning. This could lead to the development of more authentic and meaningful assessment methods, which measure students' knowledge and ability to apply it in diverse contexts. In addition to the abovementioned opportunities, implementing SG in physics education can improve teacher training. Blackie et al.[14] argue that incorporating SG into physics teacher education programs can provide future educators with a valuable tool to reflect on their teaching practices and improve their ability to facilitate student learning. This could lead to a paradigmatic shift in how physics teachers are prepared, emphasizing not only mastery of content but also the ability to navigate and guide students through different levels of abstraction.

Conclusion

The present study aimed to analyze the applicability of SG as a conceptual tool to understand and improve contextualization in physics teaching. Through a thorough literature review and a critical analysis of SG's theoretical and practical implications, we have reached several significant conclusions that address the objectives initially stated.

First, this work has evidenced that SG, as part of the Legitimation Codes Theory, offers a robust theoretical framework and a practical tool to address persistent challenges in physics teaching. SG's ability to conceptualize and analyze the movement between the concrete and the abstract in physics teaching gives educators a new perspective on structuring their lessons and activities.[8] This approach can significantly improve students' conceptual understanding and ability to apply physical principles in diverse contexts.

In the context of the notion of SG, semantic profiles were shown to evidence the ability to move fluidly between different levels of SG and how their employment can be reclaimed to promote deep conceptual understanding in physics.[5] This concept provides a theoretical basis to explain why some students struggle to transfer knowledge between contexts and offers a strategy to address this challenge.

The study also revealed that implementing SG in physics teaching presents significant opportunities and challenges. On the one hand, SG offers the possibility of developing more inclusive teaching practices and authentic assessments.[4] On the other hand, effective implementation of SG requires teachers' deep understanding of the concept and a substantial revision of existing curricular materials.[6] In terms of practical implications, this research suggests that incorporating SG into teacher education programs could significantly impact the quality of physics teaching. As Blackie et al.[14] point out, SG can provide future educators with a valuable tool to reflect on their teaching practices and improve their ability to facilitate student learning. This could lead to a paradigmatic shift in how physics teachers are prepared, emphasizing not only mastery of content but also the ability to navigate and guide students through different levels of abstraction.

However, it is essential to acknowledge the limitations of our study. The practical application of SG in physics teaching remains a relatively unexplored area, and further empirical research is needed to validate its efficacy fully in diverse educational contexts. Furthermore, the complexity of the SG concept and its implementation may present challenges for its widespread adoption in teaching practice. Despite these limitations, our study contributes to physics didactics by providing a deeper understanding of how SG can be applied to improve contextualization and conceptual understanding in physics teaching. The results of this research have important implications for curriculum design, teacher training, and the development of educational resources in physics.

Looking ahead, several lines of research emerge as particularly promising. First, empirical studies are needed to examine the effectiveness of SG-based interventions in diverse physics teaching contexts, from secondary to university education. These studies provide concrete evidence on how conscious manipulation of SG affects learning and knowledge transfer in physics. Second, future research could explore how SG can be more effectively integrated into the design of assessments in physics. Steenkamp et al.'s[17] work on using SG to analyze student solutions to physics problems provides an exciting starting point for this line of research. Further studies are needed to develop and validate assessment tools that can effectively capture students' ability to navigate between different levels of SG.

Finally, SG offers a robust theoretical framework and a practical tool to address persistent challenges in physics teaching. Its potential to improve contextualization, conceptual understanding, and knowledge transfer in physics is significant. As we continue exploring and refining SG's application in physics teaching, we will likely see new innovative pedagogical strategies emerge that can transform how we teach and learn this fundamental discipline. The path toward more effective and meaningful physics teaching through the application of SG is promising, and we hope that this study will inspire future research and practice in this direction.

Acknowledgments

None.

Conflicts of interest

None.

References

1. Bao L, Cai T, Koenig K, et al. Learning and scientific reasoning. *Science.* 2018;323(5914):586–587.
2. Marshman EM, Kalender ZY, Nokes–Malach T, et al. Female students with A's have similar physics self–efficacy as male students with C's in introductory courses: A cause for alarm? *Physical Review Physics Education Research.* 2019;15(1):010132.
3. Maton K. Making semantic waves: A key to cumulative knowledge–building. *Linguistics and education.* 2013;24(1):8–22.
4. Kelly GJ, McDonald S, Wickman PO. Science learning and epistemology. In K. S. Taber & B. Akpan (Eds.), Science education (pp. 139–151). Sense Publishers. 2017.
5. Georgiou H, Sharma MD. Characterizing the use of physics knowledge in unexpected contexts. *Research in Science Education.* 2022;52(1):209–234.
6. Hazari Z, Sonnert G, Sadler PM, et al. Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching.* 2017;54(8), 937–955.
7. Georgiou H, Sharma MD. Does active learning in thermodynamics lectures improve students' conceptual understanding and learning experiences? *European Journal of Physics.* 2015;36(1):015020.
8. Georgiou H, Maton K, Sharma M. Recovering knowledge for science education research: Exploring the "Icarus effect" in student work. *Canadian Journal of Science, Mathematics and Technology Education.* 2020;20(4):667–680.
9. Conana H, Marshall D, Case JM. Exploring pedagogical possibilities for transformative approaches to academic literacies in undergraduate physics. *Studies in Higher Education.* 2020;45(11):2369–2381.
10. Mazzitelli CA, Guirado AM, Chacoma MS. Análisis de la dimensión semántica en contextos de digitalización forzada: el caso de la enseñanza de termodinámica introductoria. *Revista de Enseñanza de la Física.* 2023;35(2):27–43.
11. Santos BF, Mortimer EF. Ondas semânticas e a dimensão epistêmica do discurso na sala de aula de química. *Investigações em Ensino de Ciências.* 2019;24(1):62–80.
12. Kirk S. Waves of reflection: Seeing knowledge in academic writing. In J. Kemp (Ed.), EAP in a rapidly changing landscape: Issues, challenges and solutions (pp. 109–118). Garnet Education. 2017.
13. Macnaught L, Maton K, Martin JR. Jointly constructing semantic waves: Implications for teacher training. *Linguistics and Education.* 2020;55:100776.
14. Blackie MA, Le Roux K, McKenna S. Possible futures for science and engineering education. *Nature Reviews Physics*. 2021;3(10):678–684.
15. Maton K, Chen RTH. LCT in qualitative research: Creating a translation device for studying constructivist pedagogy. In K Maton, et al. (Eds.), Knowledge–building: Educational studies in Legitimation Code Theory (pp. 27–48). Routledge. 2016.
16. Szenes E, Tilakaratna N, Maton K. The knowledge practices of critical thinking. In M. Davies & R. Barnett (Eds.), The Palgrave Handbook of Critical Thinking in Higher Education (pp. 573–591). Palgrave Macmillan. 2015.
17. Steenkamp R, Rootman–le Grange I, Müller–Nedebock KK. Semantic waves in physics education: A case study of a high–achieving student's solutions to physics problems. *Research in Science Education.* 2021;51(6):1637–1655.
18. Langsford S. Using semantic waves to guide students through the research process: From topic selection to evidence evaluation. *Journal of Information Literacy.* 2021;15(1):68–82.
19. Cutrera G, Silva Júnior AJ, dos Santos BF. Gravedad semántica y formación docente en química: Un estudio de caso centrado en procesos de contextualización del contenido de la escritura reflexiva. *InterMeio: Revista do Programa de Pós–Graduação em Educação–UFMS.* 2021;28(55):94–115.
20. Maton K. Knowledge and knowers: Towards a realist sociology of education. *Routledge.* 2014.
21. Maton K. Semantic waves: Context, complexity and academic discourse. In A. Maton, S. Hood, & S. Shay (Eds.), Knowledge–building: Educational studies in Legitimation Code Theory (pp. 59–85). Routledge. 2020.
22. Maton K, Chen RTH. Specialization codes: Knowledge, knowers and student success. In A. Maton, S. Hood, & S. Shay (Eds.), Knowledge–building: Educational studies in Legitimation Code Theory (pp. 35–58). Routledge. 2020.

Citation: Cutrera G. Rethinking contextualization in physics education: a perspective from semantic gravity. *Phys Astron Int J.* 2024;8(5):217–223.
DOI: 10.15406/paij.2024.08.00351