

Enhancing Semantic Gravity through Practical Work: A Case on Semiconductors in Grade 12

By Angeline Duma , Sphamandla Innocent Zulu[‡],
Emmanuel Mushayikwa[•] & Ngonidzashe Mushayikwa[◦]*

Students often struggle to connect abstract science concepts with real-world experiences, limiting their ability to build cumulative understanding. This qualitative case study examined a Grade 12 Technical Sciences lesson on semiconductors. The observed lesson was transcribed and analysed using Legitimation Code Theory (LCT), specifically the concept of semantic gravity, to examine shifts between abstract and concrete knowledge forms. The findings show how the teacher transitioned between abstract and concrete forms of understanding and demonstrate that the intentional use of practical work extends the semantic range of the lesson. This extended semantic range enabled clearer transitions between abstract and concrete knowledge, thereby promoting cumulative knowledge building. Within the Legitimation Code Theory framework, the study highlights how practical work strengthens the link between theory and practice and offers insights for teachers seeking to design more meaningful science lessons.

Keywords: Practical work, Semantic gravity, Legitimation Code Theory (LCT)

Introduction

Science teaching and learning is complex as it involves grappling with abstract and difficult concepts (Balla et al., 2024; DoE, 2014; Sarabi & Gafoor, 2018). Traditional approaches that focus primarily on the transmission of knowledge have been found insufficient for addressing these challenges (Millar, 2004). As a result, students often struggle to understand and apply scientific concepts effectively, leading to fragmented or surface-level learning which limits their ability to transfer knowledge to new contexts. Previous research emphasises the necessity of involving students directly in scientific practices, rather than restricting instruction to the passive acquisition of knowledge (National Academies of Sciences, Engineering & Medicine, 2015). Practical work, when integrated effectively into lessons, has been shown to improve academic performance, provide concrete representations of abstract phenomena, and connect theoretical concepts to real-life experiences (Shana & Abulibdeh, 2020; Osborne, 2015). However, in many classroom contexts, practical work tends to function primarily as a demonstration, rather than as an intentional pedagogical tool for explicitly linking theory and practice (Abraham & Millar, 2008).

*Lecturer, University of the Free State, South Africa.

[‡]Lecturer, University of the Witwatersrand, South Africa.

[•]Senior Lecturer, University of the Witwatersrand, South Africa.

[◦]PhD candidate, University of the Witwatersrand, South Africa.

This limited pedagogical use points to the need for deliberate lesson design that fosters clear connections between abstract concepts and practical experiences.

This study addresses this gap by exploring how science teachers can intentionally design lessons that bridge abstract scientific concepts and practical experiences, enabling cumulative knowledge building. Cumulative knowledge building refers to learning in which new understanding builds upon prior knowledge, integrating both abstract and concrete elements (Maton, 2009; Walton & Ruznyak, 2019). According to Clarence (2013), the absence of explicit links between theory and practice results in segmented learning, in which knowledge becomes difficult to recall, recognise, and apply across different contexts.

To explore how abstract and concrete forms of knowledge can be enacted in practice, this study uses the Legitimation Code Theory (LCT) dimension of semantic gravity (SG), which describes the degree to which teachers take abstract concepts and bring them closer to the learner's everyday lives or real-world situations (Walton & Ruznyak, 2019). The primary aim of this study is to examine how practical work strengthens semantic gravity (SG) in the context of a lesson on semiconductors for grade 12. The practical work component of the lesson is not separate from the observed general lesson, so the study focuses on how the teacher generally shifts between abstract and concrete forms of understanding in the overall lesson, later revealing how practical work strengthened the semantic gravity of the overall lesson.

Research Questions

- I. What transitions does the teacher make between abstract and concrete forms of understanding when teaching the concept of semiconductors?
- II. How does practical work strengthen the semantic gravity of the lesson?

Literature Review

Practical Work in Science Teaching

Science teaching aims to build scientific knowledge by initiating learners into scientific ways of doing and seeing the world (Kelly, 2014). To achieve this, teachers use various strategies, including practical work, which involves students observing and/or manipulating real objects and materials. The importance of practical work in teaching and learning is widely advocated for in science education (Abrahams & Millar, 2008; Ferreira & Morais, 2020; Millar, 2010; Oliveira & Bonito, 2023). Practical work is essential because it offers a practical representation of scientific phenomena and provides students with the hands-on experience needed to understand scientific processes and ideas. Studies have shown that including practical work in teaching improves academic performance and helps students recognise the link between theory and practice, which in turn strengthens their conceptual understanding (Evagorou et al., 2015; Gott & Duggan, 1996; Jokiranta, 2014). Furthermore, practical work can

help students see science as relevant to their daily lives, making scientific concepts meaningful and accessible for students.

However, the role of practical work is often understood at a surface level, functioning as a means to an end rather than as a deliberate pedagogical process. While practical work is commonly regarded as effective in bridging theory and practice, the mechanisms through which this connection is achieved are not always made explicit. Consequently, the relationship between these two forms of knowledge, although acknowledged as important, often remains invisible in classroom practice. The literature suggests that for effective knowledge building, practical work must engage students in purposeful thinking processes (Jokiranta, 2014), followed by structured discussions to interpret observations and measurements (Millar, 2004). However, what remains underexplored is how such thinking processes and discussions are pedagogically organised to make shifts between abstract and concrete knowledge visible in classroom practice. The need to make connections between abstract and concrete knowledge explicit is especially pronounced in topics characterised by microscopic or invisible processes, such as those encountered in the teaching of semiconductors in technical Sciences.

The Topic of Semiconductors in Technical Science Education

The topic of semiconductors is introduced in Grade 10 as materials whose conductivity increases with temperature (Rollnick et al., 2013). Although this topic is largely located in the discipline of engineering, there are basic physics and chemistry concepts underlying how the topic works. The link between the topic and engineering is what makes the topic important in technical science classrooms. According to the Department of Basic education (DoE, 2014), the topic must be taught practically for effective meaning-making. Yu et al. (2022) adds that students are encouraged to actively participate in class to apply the knowledge they have gained about the topic of semiconductors. Bakhtibaeva et al. (2016) justified the use of ICT to integrate the model and full experiment scale in semiconductors instruction. This study is concerned with showing how the abstract concepts are then linked with practical elements for meaning making on the topic of semiconductors or vice versa. Given the difficulties experienced by learners in understanding the topic of semiconductors (Garcia-Carmona & Criado, 2009), it is important to understand how teachers pedagogically approach the topic. Though Rollnick (2017) developed teachers' content knowledge (CK) and pedagogical content knowledge (PCK) for the semiconductor topic, it remains unclear how teachers teach this practical topic after their CK and PCK has been strengthened, especially in the context of technical science education. Technical science, by nature, requires to be taught through the infusion of practical activities (DoE, 2014) aimed at helping learners grasp the abstract concepts. Limited research has been done on this topic, particularly on how teachers build scientific knowledge about it in the classroom. The limited studies on teaching semiconductors point to a need to examine how teachers build scientific knowledge of the topic in technical science classrooms.

Conceptual Framework

From the existing literature, it is unclear how the connection between abstract concepts and real-life experiences is made explicit in practice. While studies confirm that linking abstract concepts to real experiences is beneficial for student understanding and helps them recognise the link between theory and practice, they often focus on practical work as means to the end without explaining the underlying processes. A study by Abraham and Millar (2008) found that although practical work successfully engaged learners in hands-on activities, it did not necessarily enable them to make explicit connections between the practical tasks and the underlying theoretical concepts. We address this gap by using the semantic gravity code of the Legitimation Code Theory (LCT) to provide insight into how this link-making can be enacted and made visible in practice.

This study draws on the concept of semantic gravity from Legitimation Code Theory (LCT) (Maton, 2014) to examine how cumulative knowledge building occurs in a Grade 12 technical sciences lesson on semiconductors. LCT is a sociological framework that foregrounds knowledge and its organisation in educational practice (Maton & Doran, 2019). Semantic gravity is the degree to which abstract concepts are contextualised in students' everyday experiences (Walton & Rusznyak, 2019), allowing for an analysis of shifts between abstract and concrete forms of knowledge. In science education, where learners engage with complex and often invisible processes, such shifts are critical for enabling meaningful access to disciplinary knowledge (Maton & Doran, 2021). This study examines how practical work is used to strengthen links between abstract and concrete experiences in the teaching of semiconductors.

According to Maton (2014) semantic gravity can be relatively stronger (SG+) or weaker (SG-) with unlimited variations. When meaning remains too abstract (SG-), learners may fail to apply knowledge in other contexts, conversely, when meaning remains too closely related to learners' everyday experiences (SG +), understanding of the disciplinary concepts may be hindered. Thus, learning is cumulative when ideas shift between weaker (-) or stronger semantic gravity (+) overtime in a lesson and vice versa (Hugo, 2014). In a learning situation, teachers can either weaken or strengthen semantic gravity. Martin et al. (2020) contends that the weakening of semantic gravity refers to a teachers' shift from specific case details to generalisations and abstractions, while the strengthening of semantic gravity refers to a shift from generalised or abstract ideas to concrete and delimited cases. The shifts in semantic gravity over time during the lesson can be represented in a semantic profile, which is necessary for comprehending and analysing cumulative knowledge building as it provides an explicit visual representation (Maton, 2014). Abstract understandings in this study are characterised by SG-, whereas concrete understandings have varying degrees listed from weaker to stronger (SG+, SG++, SG+++). Furthermore, SG+ has varying levels of strength. For example, using a hypothetical example is a lower level of SG+ denoted as SG+ (one), whereas using diagrams is slightly higher (SG+, two). The associated meanings of these semantic codes are operationalised through a translation device to guide the analysis of shifts between abstract and concrete knowledge.

Methodology

This study employs a qualitative case study approach, guided by the semantic gravity dimension of Legitimation Code Theory (LCT), to examine cumulative knowledge-building practices during a Grade 12 technical sciences lesson on semiconductors. The study is qualitative in nature, as it focuses on in-depth analysis of classroom interactions and meaning-making processes within a single bounded case rather than on numerical measurement or statistical generalisation. LCT was selected for its suitability as an analytical and organising framework for classroom data (Clarence, 2013). In this study, the semantic gravity dimension of LCT directly informs the research design and analysis, as the research questions focus specifically on identifying transitions between abstract and concrete forms of understanding and examining how practical work strengthens these shifts. Semantic gravity provides the conceptual tools to trace these movements systematically across the lesson. Data were collected through classroom observation. A fifty-minute lesson, taught by an experienced technical sciences teacher, was video recorded and transcribed for analysis. Ethical considerations were addressed by ensuring the anonymity of the teacher and learners through face blurring in the final report.


To explicitly capture how the teacher moved between abstract and concrete knowledge forms without omitting any important detail, the lesson was divided into five episodes, each lasting approximately ten minutes. This episodic structuring enabled systematic tracking of semantic gravity shifts across time, thereby directly addressing research question 1, which seeks to identify the transitions the teacher makes between abstract and concrete forms of understanding. Each episode was analysed and coded using semantic gravity codes. Four semantic gravity codes were identified (SG-, SG+, SG++, and SG+++), and their specific meanings are outlined in the translational device (see table 1). The translational device facilitated interaction between theory and data, clearly showing how and why segments of the lesson were coded in a specific manner (Cowsley-Haselden, 2020). The coded data were further represented using semantic profiles which are useful for visualising the teacher's shifts between abstract and concrete knowledge over time, thereby revealing transitions that support cumulative learning (Xie, 2020).

In addition to semantic coding, thematic analysis was utilised to identify recurring patterns in how knowledge was built and connected across the lesson. Codes derived from the semantic gravity analysis were examined for patterned meaning and grouped into themes reflecting key knowledge-building processes. These themes were derived from the coded data and therefore complement semantic analysis rather than replace it, thus providing an additional layer of interpretation for the presentation of findings.

A key strength of this methodological approach is that the translational device acts as a language of description (Cowsley-Haselden, 2020), enhancing the transparency of the semantic coding process. This ensures that the codes and themes generated are grounded in the empirical data. In addition, the translational device strengthens the replicability and transferability of the findings by making the analytical procedures explicit, thereby enabling other researchers to follow and apply the analysis process. Given that the focus was on a single lesson, findings therefore

cannot be generalised, however, the approach used provides rich, detailed insights into how semantic gravity operates in practice and how practical work contributes to cumulative knowledge building.

Table 1. Semantic Gravity (SG) Translational Device (shows how abstract or concrete meaning is)

Strength	Code	Indicator	Examples from the analysed lesson transcriptions
Weaker  Stronger	SG-	The teacher explains statements in an abstract manner.	“Conductivity is inversely proportional to resistivity, if the resistance is high, the conduction will be low”
	SG+	The teacher refers to a hypothetical example. Often using diagrams to illustrate.	“But there is something you need to know. Now, if you look at this electron (referring to the diagram), it’s far from the hole. So, chances are that because of this gap (referring to the diagram), it’s almost impossible for electrons to neutralise with the hole”.
	SG++	The teacher focuses on real world example/direct experience	“When I asked Kutlwano to move and I said, take those electrons. There was the first electron being removed, and then she left an empty space, and I said France must come too, and he left space, so remember that the actual things that are moving are electrons. Kutlwano and France represent electrons in this case”.
	SG+++	The teacher focuses on personal experiences	“Now, using these materials (diodes, multimeters, etc.), let us observe reverse and forward bias. Here, the teacher directs learners into conducting an experiment”.

Findings

The section is structured in two parts; it begins by reporting findings related to the first research question and subsequently utilises these findings to address the second research question. To illustrate cumulative learning processes, we present a clear account of how the teacher transitions between abstract and concrete forms of understanding, with each episode reported individually and then considered interactively in the discussion.

Theme 1: Teacher Transitions Between Abstract and Concrete Forms

The following findings addresses the question: *What transitions does the teacher make between abstract and concrete forms of understanding when teaching the concept of semiconductors?* The lesson demonstrated a semantic wave as the teacher unpacked and repacked understanding using different degrees of semantic gravity which are a core mechanism for cumulative knowledge building. This was reflected by the teacher’s ability to consistently shift from abstract concepts (SG-) to more

concrete and contextualised forms (SG+, SG++, SG+++) to unpack meaning as highlighted in the analysed episodes below.

Episode 1: Initial Abstraction and Hypothetical Shifts

The episode begins with teacher introducing concepts in an abstract manner (SG), followed by a slight strengthening of semantic gravity noted using a hypothetical example (SG+) and finally a shift back to abstract concepts related to the topic of semiconductors (SG-). The strengthening and weakening of semantic gravity from SG- to SG+ and SG+ to SG- respectively, suggests a low semantic range, limited to hypothetical illustrations. This can be seen in the extract below which illustrates how the teacher introduced the concept of semiconductors an abstract statement.

***Teacher:** The last lesson was about extrinsic semiconductors where we introduced doping as a method of increasing conductivity in semiconductors. Can you tell me exactly what doping is, from the previous lesson? What did I say about doping? Yes?*

The concept of doping as a method of increasing conductivity in semiconductors is an abstract concept that requires being unpacked using illustrations so that learners can comprehend it. Although the statement appears straightforward, understanding it requires engagement with several underlying abstract questions: What is doping? What is conductivity? And how does doping enhance conductivity in semiconductors? This statement as introduced by the teacher is framed within the framework of prior knowledge, suggesting that the concept is not new for the learners. Even so, it is worth noting that the teacher introduces it to develop an abstract understanding of the targeted concepts in this new lesson. Following the abstract statement, the teacher makes a shift from SG- (abstract) to SG+ (hypothetical example). In doing so, the teacher strengthens the semantic gravity of the lesson. A shift from abstract to concrete examples enables an entry point for learners to build mental images of the abstract concept that is introduced.

***Teacher:** When we speak of doping, we bring in a foreign element. Do you still remember the alien element? Silicon crystals if you still remember. So, we had some silicon crystal with electrons around it, and we introduced a certain element. Which element can you remember? There was an alien..... a foreign element that we used.*

***Learners:** As*

***Teacher:** As, which is what? Arsenic...and in which group is Arsenic if you look in your period table right now? It is in which group?*

***Learners:** 15*

At this point in the lesson, the teacher is unpacking meaning by attempting to explain how doping occurs in semiconductors. This strengthens the semantic gravity as the teacher moves from abstractions to forms of knowledge that learners can easily understand. The element arsenic is used as an illustration in this process, and learners are immediately redirected to their periodic tables to identify the group to which arsenic belongs. The teacher is gradually preparing to repack meaning by shifting from SG+ back to SG-, thus weakening the semantic gravity. This transition is

required because leaving the meaning too context-based or concrete may hinder learning. The extract below shows this significant shift between SG+ and SG-.

Teacher: Group 15, meaning it has how many electrons outside, the valence electrons?

Learners: 5

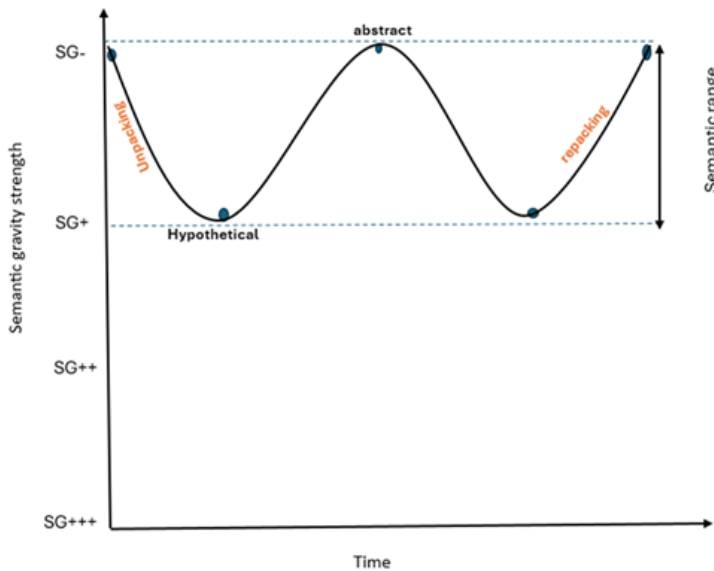
Teacher: So, if we pair the four electrons around the arsenic, what we end up having is one free electron, and because of this free electron that is able to move around, we say it forms a certain type of semiconductor, which we call an n-type. What did we say about this n? What does n stand for?

Learners: Negative

Teacher: It means there is an extra electron, so it forms an n-type.

The extract above is characterised as weakening semantic gravity since the teacher introduces concepts such as valence electrons, n-type and free electrons that require further unpacking. If these concepts are not unpacked properly, understanding may be hindered. Thus, throughout this episode, the teacher makes shifts between SG- to SG+(one) and then back to SG-. The transition from SG+ (one) to SG- is referred to as repacking, and it is represented by an upward case, indicating shifts from familiar understandings to abstract forms of knowledge. The weakening and strengthening of semantic gravity over time in this lesson enabled the teacher to make shifts between abstract and concrete forms of understanding, which were limited to hypothetical illustrations in this episode. These shifts were necessary as they allowed learners to comprehend the targeted concept, thus building cumulative knowledge. To visualise how the teacher shifts between SG- and SG+ (one) in this episode, a semantic profile indicating a semantic wave with a low semantic range is identified.

Figure 1. Semantic Profile of Episode 1



Episode 2: Introduction of Direct Experiences

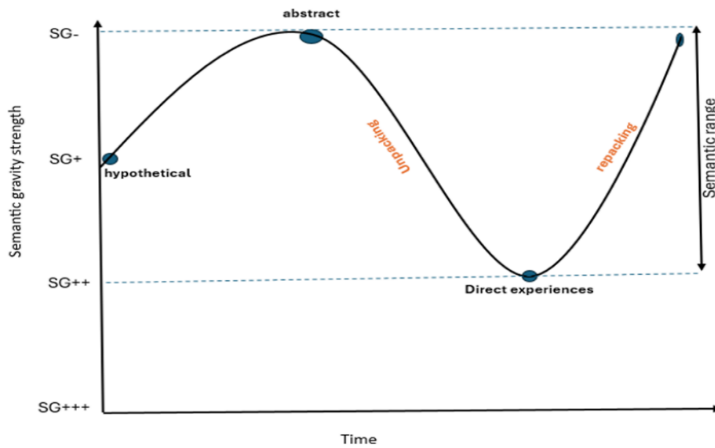
Episode 2 is characterised by shifts between SG+, SG-, SG++, and then back to SG-. This episode demonstrates transitions between hypothetical examples (SG+), abstract concepts (SG-), the introduction of direct experiences (SG++) and a shift back to the abstract concepts (SG-). This sequencing indicates a wider semantic range than episode 1. Episode 2 begins with the teacher introducing a hypothetical example (SG+). The key aspect is that explanations do not remain in these hypothetical terms; instead, the teacher repacks understanding. This leads to an upward curve (as visualised in the semantic profile below), illustrating a significant shift from concrete (SG+) to abstract forms of understanding (SG-). This was necessary as it allowed learners to link the example to the concepts of the discipline. At this point in the lesson, understanding was defined by the abstract disciplinary terms, this means that it was therefore necessary for the teacher to recontextualise meaning to create a constant loop between abstract and concrete understandings. To do this, the teacher then initiated a shift from SG- to SG++ through introducing direct learner experiences. Doing so strengthened the semantic gravity of the lesson, thereby allowing learners to connect the abstract concepts to direct experiences.

A shift to SG++ signalled a slightly stronger degree of semantic gravity, translating to a higher level of concrete understanding. At this point in the lesson, meaning and understanding are excessively contextualised or too closely linked to learners' experiences, hence, it is imperative for the teacher to repack understanding by connecting the experiences to the targeted abstract science concept. This required a shift from SG++ back to SG- thus weakening the semantic gravity of the lesson. The excerpt below demonstrates a scenario in which the teacher weakened semantic gravity by transitioning from SG++ to SG-.

Teacher: *Remember when I asked Kutlwano to move, and I said, take those electrons. There was the first electron being removed, and then she left an empty space, and I said France must come, and he left space, so remember that the actual things that are moving are electrons (the teacher was talking about a demonstration that the class previously did).*

Teacher: *Electrons now move due to the repulsion coming from the negative terminal of the battery, and even the holes will look as if they are moving. So, it means electrons are being pushed fast by the negative terminal of the battery. This movement results in a term called conduction.*

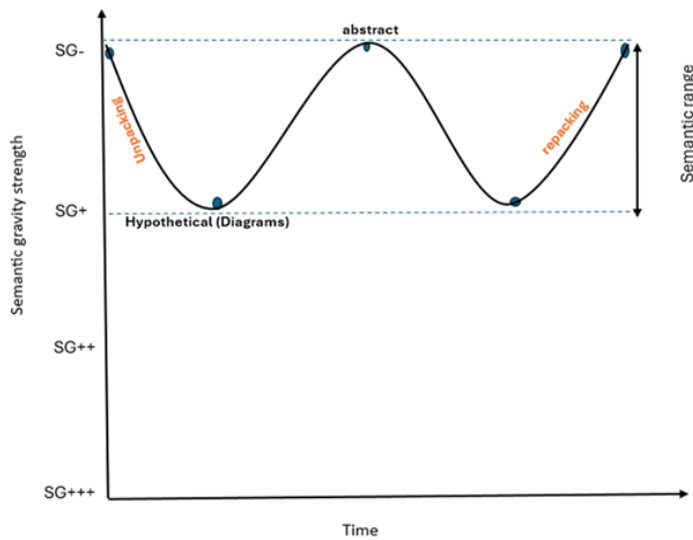
Figure 2. Semantic Profile of Episode 2



Episode 3: The Use of Visual Representations

This episode is characterised by the use of diagrams, offering a visual representation of abstract concepts like conduction. The semantic profile below depicts how abstract (SG-) and concrete (SG+) forms of knowledge shifted over time in a lesson. The teacher weakened and slightly strengthened semantic gravity, as evidenced by shifts from SG- to SG+, then SG+ back to SG-.

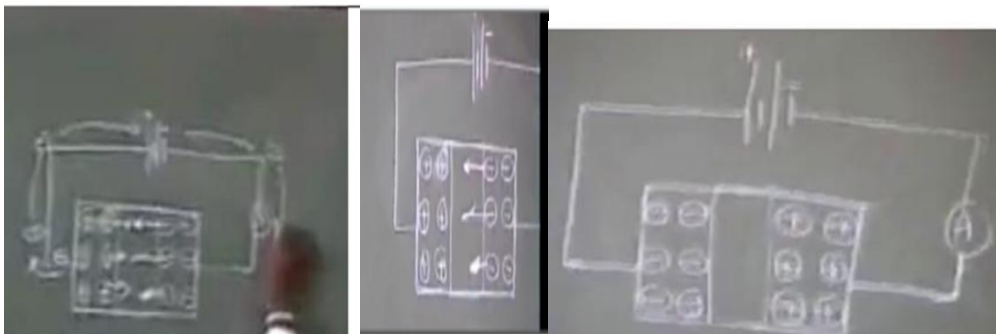
Figure 3. Semantic Profile of Episode 3



The semantic profile for this episode is similar to episode 1. What sets these two episodes apart is the type of hypothetical example that the teacher opted for (SG+, two). SG+ in episode 1 is characterised by hypothetical statements, whereas SG+ in episode 2 is denoted by representations in the form of diagrams. The diagrams presented are anchored with detailed explanations of concepts. In this episode the

teacher explains the concept of conduction and uses diagrams to help learners build mental images of how electrons move in a circuit as shown below.

Figure 4. Diagrams used to explain Abstract Concepts

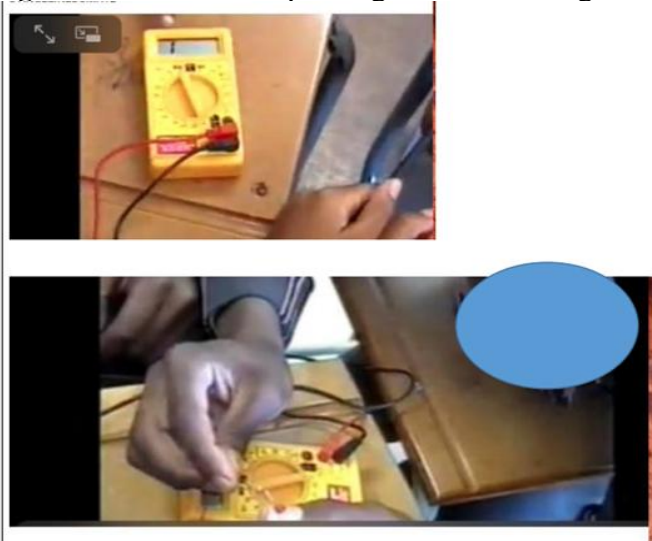


The teacher strengthens semantic gravity (SG+) through using diagrams to anchor meaning in the concrete domain. As the lesson progresses, semantic gravity is weakened (SG-), demonstrating that the diagrams function as temporary scaffolds rather than as sources of meaning in themselves. This shift marks a transition toward engagement with the abstract, disciplinary principles of science.

Episode 4: Maximum Semantic Range with Practical Work

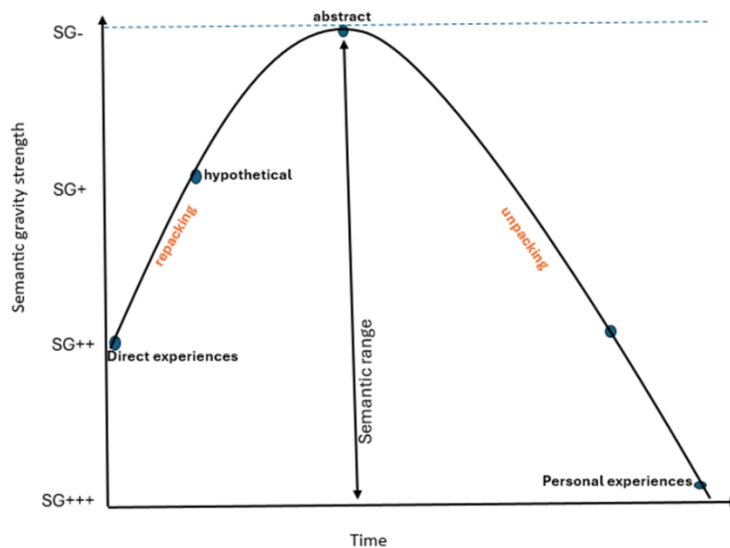
This episode presents the widest semantic range, where the teacher incorporates and manages to transition between all four codes: SG++, SG+++, SG+ and SG- while in other episodes, the weakening and strengthening of semantic gravity was limited to SG-, SG+, SG++. The episode opens with a relatively stronger semantic gravity (SG++), with a focus on learners' direct experiences. Semantic gravity is slightly weakened as the teacher transitions from SG++ to SG+, indicating a shift between direct experiences and hypothetical examples. Based on the degrees of concrete forms of knowledge identified in this study, the teacher transitions from slightly stronger semantic gravity (SG++) to slightly weaker semantic gravity involving diagrams (SG+), and finally to SG+++ involving personal experiences. The weakening of semantic gravity created clear links between direct experiences and diagrams relevant to understand the concept of semiconductors. Meaning and explanations are not limited to a hypothetical level (SG+); the teacher takes meaning to its abstract forms by shifting to SG-. This is a necessary shift that links various concrete forms of understanding to the abstract concept being taught. Following that, the teacher strengthens the semantic gravity to the highest degree by introducing a practical activity (SG+++) involving diodes and multi-meters. The introduction of the practical activity presents clear links between abstract concepts to learners' personal experiences. Learning is contextualised as learners work with the required materials, as seen below. The inclusion of SG+++ demonstrates the deepest level of contextualisation in the lesson.

Figure 5. Learners Manipulating Materials during the Practical Work



By tapping into learners' experiences, the teacher establishes explicit links between abstract and concrete forms of knowledge. The higher semantic range as observed in this episode indicates greater opportunities for cumulative knowledge building. The semantic profile below provides a visual representation of this episode.

Figure 6. Semantic Profile of Episode 4



Episode 5: Practical Work Dialogue and repacking

This episode, following the practical activity, focuses on dialogue and reflection. It is characterised by transitions from the highest level of concrete understanding (SG+++) to abstract concepts (SG-), facilitated by both the teacher and learners' engagements. In this episode, learners share their personal experiences, while others

re-do the practical; during this dialogue, learners are drawn back to the abstract concepts that the practical was intended to address. Shifts from SG+++ (personal experiences) to SG- (abstract) are observed, this transition is mainly facilitated by the learners. Learners' involvement in this dialogue helps them see the relevancy of the practical activity. See extract below:

Teacher: How was your experience using the diodes and observing the reverse and forward biases?

Learner 1: It was interesting to see the current flow.

Teacher: Good Teacher: Can someone from the next group share their experience?

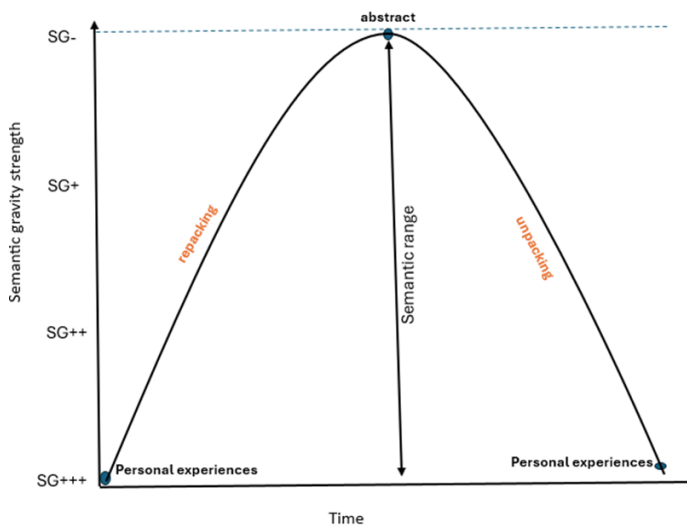
Learner 2: Sometimes it is scary because you are thinking, what if I break these things.

Teacher: Okay. That is the only problem. Can anyone from this group tell us about their experience?

Learner 3: We had a fault with our LED because it did not light up, we think the problem could have been the battery. We are hoping that we redo and see how it works out.

Teacher: Can another group send their materials so that this group can quickly observe the forward bias and reverse bias using the LED. Let us give them a chance before we move on.

Figure 7. Semantic Profile of Episode 5



Theme 2: Practical Work and Semantic Gravity Enhancement

The analysis of episodes 4 and 5 directly addresses the research question: *How does practical work strengthen the semantic gravity of the lesson?* Both episodes 4 and 5 demonstrate how the teacher was able to transition between SG- and SG+++ , giving those episodes the highest semantic gravity range. The introduction of the practical activity allowed the teacher to tap into learners' personal experiences, thereby creating a direct link between theory and practice. The inclusion of the practical segment in the lesson meant that understanding was grounded in learners' personal experiences as they interacted directly with the materials used in the task,

and this strengthened the semantic gravity of the overall lesson. Furthermore, the practical activity enabled a meaningful dialogue between the teacher and learners. Encouraging learners to ask experience-related questions further personalised learning and enhanced semantic gravity. For example, the teacher asked, “Is this a forward bias? How do you know? Is there any light from the LED?” To answer these questions, learners drew on the practical and theoretical understanding offered throughout the lesson.

Additionally, when learners were performing the practical task, the teacher shaped their knower gaze by specifically showing them that practical work is a form of trial and error and that when the results contradict the theory, they must redo the practical for verification. See the extract below.

Teacher: Can others share their experiences? What can you say about the multimeter? Is there forward bias in the multi-meter?

Learner: There was a reading for the reverse bias.

Teacher: Let's redo the practical to see if you are telling us the truth.

Learners redo the practical and later realise that there is no reading for the reverse bias only in the forward bias.

Teacher: See, it means your group didn't do it right. Now listen, class, the next activity is coming, and we are moving back to our positions. This will be a small activity for about ten minutes on your own. Okay?

In reverse bias, our LED will not glow up, and the multi-meter will not show any readings because there is no conduction. Remember, conduction is the movement of electrons, this means that in reverse bias, electrons are not able to move, as I explained earlier. But in forward bias, our LED glows up, and the multi-meter shows a reading because there is conduction.

Learners were made aware of the different kinds of knowledge and skills required when engaging in the practical task. The teacher made explicit how learners were expected to perform the scientific task and guided them in using the materials correctly. Learners were clearly shown the skills related to the content, enabling them to build connections between theory and practice and apply the knowledge in different situations. This instance, as shown during the practical component of the lesson, enhanced the semantic gravity.

Discussions and Implications

Episodes 1–3 illustrate how the teacher established a semantic wave by transitioning between abstract and concrete forms of knowledge to support conceptual understanding. Episodes 4 and 5 extend this movement through the introduction of practical work, which strengthened semantic gravity to its highest level (SG+++). Together, these episodes demonstrate that practical work functions not merely as reinforcement, but as a pedagogical mechanism for enhancing semantic gravity and deepening cumulative knowledge building.

The primary finding is that the teacher navigated the lesson through purposeful transitions between abstract (SG-) and various concrete (SG+, SG++, SG+++) forms of knowledge. Such movement is crucial because confining meaning to only abstract or only concrete forms restricts knowledge transfer and cumulative learning (Maton, 2014). Science education research has long noted that learners struggle to grasp abstract scientific concepts when teaching emphasises transmission rather than conceptual engagement (Balla et al., 2024; Sarabi & Gafoor, 2018). Using LCT's semantic gravity dimension provided methodological visibility into how theory and practice were explicitly linked. The progressive increase in contextualisation, culminating in SG+++ during the practical activity, demonstrates a powerful pedagogical approach. The high semantic range observed in episodes 4 and 5 suggests that the most effective segment for cumulative knowledge building was the one incorporating direct, hands-on experimentation. This supports arguments that practical engagement enables deeper understanding and transfer of scientific knowledge (Millar, 2004; National Academies of Sciences, Engineering, and Medicine, 2015).

The patterns observed in episode 1 highlight the importance of moving between abstraction and contextualisation. Beginning with abstract disciplinary knowledge provides access to core scientific meaning, while subsequent contextualisation enables learners to form mental images and conceptual understanding (Jaakkola & Veermans, 2015; Lindsay, 2011). However, remaining at the level of illustration without returning to disciplinary meaning may result in fragmented understanding, limiting knowledge transfer (Hassan, 2017). The shifts between unpacking and repacking observed in the lesson reflect the movement necessary for cumulative knowledge building and conceptual consolidation (Singh et al., 2013; Byers, 2018).

Episode 2 further demonstrated that drawing on learners' experiences strengthens conceptual engagement and supports abstraction. Connecting ideas to lived experience helps learners develop meaningful mental associations and supports the development of scientific understanding (Blackie, 2014). Maton (2014) further argues that the answer to academic success is not having a stronger or weaker semantic gravity (SG) but rather having a wider range of movement between them.

The use of diagrams in episode 3 illustrates how visual representations support transitions between concrete and abstract knowledge. Visual representations help learners visualise conceptual relationships and support the linking of ideas and concepts (Alabi, 2024; Harris, 2000). In this lesson, diagrams functioned as scaffolds that anchored meaning before learners returned to abstract disciplinary principles. While these episodes demonstrate how semantic waves support conceptual access, they remain largely within hypothetical and visual scaffolds.

The introduction of practical work in episodes 4 and 5 marked a significant shift in semantic gravity by extending learning into learners' personal experience. This finding aligns with research emphasising the importance of practical work in science learning (Ferreira & Morais, 2020; Oliveira & Bonito, 2023). Practical work provides concrete representations of scientific concepts and supports deeper engagement with disciplinary knowledge. However, prior research has cautioned that practical tasks do not automatically lead to conceptual understanding if connections to theory remain implicit (Abrahams & Millar, 2008). By making semantic gravity shifts visible, this study shows how the teacher moved from abstract theory (SG-), through

contextualised forms (SG+, SG++), to hands-on engagement (SG+++), and back to abstraction using learners' observations to repack meaning. This demonstrates that practical work must be deliberately structured to avoid segmented learning and should engage learners in discussion to interpret observations.

Furthermore, the practical activity enabled meaningful dialogue between the teacher and learners. Encouraging learners to share experiences and respond to probing questions personalised learning and strengthened semantic gravity, thereby promoting engagement and deeper understanding (Blackie, 2014; Hassan, 2017). Incorporating learners' ideas and experiences helps connect science concepts to everyday life and improves the learning environment (Kervinen et al, 2020). In addition, making explicit the knowledge and skills required for scientific tasks also supports learners in recognising what counts as legitimate participation in science learning (Clarence & McKenna, 2017). This demonstrates to learners the relevancy of learning science and being part of the scientific enterprise.

Overall, the findings indicate that while semantic transitions support conceptual access, practical work extends semantic gravity to its deepest level by grounding abstract concepts in learners' personal experience. As argued by Maton (2014) the wider the knowledge range, the greater the opportunities for cumulative knowledge building. In addition, when practical work is integrated with structured dialogue and explicit conceptual repacking, it strengthens conceptual understanding and supports cumulative knowledge building (Blackie, 2014). Effective science teaching therefore requires deliberate movement between abstract disciplinary meaning and contextualised experience to enable learners to build interconnected and transferable knowledge.

Conclusions and Recommendations

This qualitative case study, using the Legitimation Code Theory's (LCT) concept of semantic gravity (SG), investigated a Grade 12 technical sciences lesson on semiconductors to examine the relationship between practical work and the explicit linking of abstract theory with concrete experience. The findings confirm that the teacher effectively employed a semantic wave pedagogy, evidenced by the recurrent shifts between abstract (SG-) and increasingly concrete forms of understanding (SG+, SG++, SG+++). The major finding is that the introduction of the practical work component (SG+++), significantly enhanced the overall lesson by facilitating the widest semantic range observed across all episodes. This maximum semantic range provided the greatest opportunity for cumulative knowledge building because it grounded the most abstract concepts (e.g., forward and reverse bias) in learners' personal experiences and hands-on experiences. The study concludes that practical work, when explicitly integrated to provide a direct link between theory and practice, is not merely a curricular requirement but a powerful pedagogical tool that strengthens semantic gravity. We argue that science teachers should adopt pedagogies that intentionally utilise practical work to make the connection between abstract theory and concrete practice visible and meaningful for learners. LCT's semantic gravity dimension serves as a methodological tool that helps teachers visualise links between theoretical and practical knowledge during instruction. The semantic profiles offer a

visual analytical means for diagnosing and strengthening theory–practice alignment in teaching.

While the in-depth, qualitative analysis provides rich insight into the mechanisms of semantic gravity, the findings may not be generalisable to all science teaching contexts or topics. Therefore, future research could be strengthened by conducting a comparative study examining the semantic profiles of multiple teachers teaching the same topic (e.g., semiconductors) with and without an integrated practical component to quantitatively assess the difference in the resulting semantic range and wave fluency. Lastly, our analysis focuses exclusively on the teacher’s transitions, without directly measuring the corresponding change in students’ cumulative understanding. It is for this reason; we recommend a further investigation of the impact of the observed semantic wave pedagogy on student learning outcomes using pre-tests and post-tests designed to measure both abstract conceptual understanding and the ability to apply that knowledge in practical contexts.

Summary

This qualitative case study examined how practical work strengthens semantic gravity in a Grade 12 technical sciences lesson on semiconductors. The study addressed the problem that learners struggle to connect abstract scientific concepts with real-world experiences, resulting in limited cumulative knowledge building. It investigated the teachers’ transitions between abstract (SG–) and concrete (SG+, SG++, SG+++)) forms of understanding and how practical work enhanced these shifts. Guided by the semantic gravity dimension of LCT, a fifty-minute lesson was video recorded, transcribed, divided into five episodes, and analysed using a translational device and semantic profiles to track shifts over time. The findings show that the teacher enacted a semantic wave by moving between abstract and concrete forms of knowledge in the overall lesson. While early episodes reflected a narrower semantic range, the introduction of practical work extended semantic gravity to the stronger level (SG+++), producing the widest semantic range in the lesson. This strengthened the link between theory and practice and supported cumulative knowledge building.

References

- Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International journal of science education*, 30(14), 1945-1969.
- Alabi, M. (2024). Visual learning: The power of visual aids and multimedia. *Journal of Educational Technology*, 15(4), 123-135.
- Bakhtibaeva, S. A., Grinshkun, V. V., Berkimbaev, K. M., & Turmambekov, T. A. (2016). Use of information technology in teaching semiconductors physics. *Indian Journal of Science and Technology*, 9(19), 93892.
- Balla, F. S. J., Jaafar, S. H., Sabbaha, N. A., Jaafar, A. S. H., Abdurahman, N. A., Jailani, A. B., ... & Rahimullah, R. J. (2024). Challenges in Learning Sciences Among Senior High School Science, Technology, Engineering, And Mathematics (STEM) Students of Private School in Indanan, Sulu. *Ignatian International Journal for Multidisciplinary Research*, 2(4), 1724-1738.

- Blackie, M. A. (2014). Creating semantic waves: Using Legitimation Code Theory as a tool to aid the teaching of chemistry. *Chemistry Education Research and Practice*, 15(4), 462-469.
- Byers, S. *An LCT Examination of Comprehension and Pedagogy in Middle Years English and Science* (Doctoral dissertation, University of Wollongong).
- Clarence, S., & McKenna, S. (2017). Developing Academic Literacies through Understanding the Nature of Disciplinary Knowledge. *London review of education*, 15(1), 38-49.
- Clarence, S. L. (2013). *Enabling cumulative knowledge-building through teaching: A Legitimation Code Theory analysis of pedagogic practice in law and political science* (Doctoral dissertation, Rhodes University).
- Cowley-Haselden, S. (2020). Building knowledge to ease troublesomeness: Affording theory knowledge ability through academic reading circles. *Journal of University Teaching and Learning Practice*, 17(2), 1-16.
- DoE. (2014). Curriculum and assessment policy statement (CAPS): *Technical Sciences*. Retrieved 30 March 2021, from <https://cms.fedsas.org.za/>
- Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to 'seeing' how science works. *International journal of Stem education*, 2(1), 11.
- Ferreira, S., & Morais, A. M. (2020). Practical work in science education: Study of different contexts of pedagogic practice. *Research in Science Education*, 50(4), 1547-1574.
- García-Carmona, A., & Criado, A. M. (2009). Introduction to semiconductor physics in secondary education: evaluation of a teaching sequence. *International Journal of Science Education*, 31(16), 2205-2245.
- Godwin, O., Adrian, O., & Johnbull, E. (2015). The impact of physics laboratory on students offering physics in Ethiopie West Local Government Area of Delta State. *Educational Research and Reviews*, 10(7), 951-956.
- Gott, R., & Duggan, S. (1996). Practical work: its role in the understanding of evidence in science. *International Journal of Science Education*, 18(7), 791-806.
- Harris, R. L. (2000). *Information graphics: A comprehensive illustrated reference*. Oxford University Press.
- Hassan, S. L. (2017). Tutors' role in tutorials: 'unpacking' and 'repacking' during the semantic journey. *South African Journal of Higher Education*, 31(3), 99-115.
- Hugo, W. (2014). Semantic density and semantic gravity. *Journal of Education*, 59, 1-14.
- Jaakkola, T., & Veermans, K. (2015). Effects of abstract and concrete simulation elements on science learning. *Journal of Computer Assisted Learning*, 31(4), 300-313.
- Jokiranta, K. (2014). The effectiveness of practical work in science education.
- Kelly, G. J. (2014). Discourse practices in science learning and teaching. *Handbook of Research on Science Education, Volume II*, 321-336.
- Kervinen, A., Roth, W. M., Juuti, K., & Uitto, A. (2020). The resurgence of everyday experiences in school science learning activities. *Cultural studies of science education*, 15(4), 1019-1045.
- Lindsay, P. (2011). Abstract teaching for a concrete world: A lesson from Plato. *PS: Political Science & Politics*, 44(3), 605-610.
- Martin, J. R., Maton, K., & Doran, Y. J. (2020). Accessing academic discourse. *Systemic Functional Linguistics and Legitimation Code Theory*. Londres y Nueva York: Routledge.
- Maton, K., & Doran, Y. J. (2021). Constellating science: How relations among ideas help build knowledge. In *Teaching science* (pp. 49-75). Routledge.
- Maton, K. (2009). Cumulative and segmented learning: Exploring the role of curriculum structures in knowledge-building. *British journal of sociology of education*, 30(1), 43-57.

- Maton, K. (2013). Making semantic waves: A key to cumulative knowledge-building. *Linguistics and education*, 24(1), 8-22.
- Maton, K. (2014). Building powerful knowledge: The significance of semantic waves. In *Knowledge and the future of the curriculum: International studies in social realism* (pp. 181-197). London: Palgrave Macmillan UK
- Millar, R. (2004). The role of practical work in the teaching and learning of science. *Commissioned paper-Committee on High School Science Laboratories: Role and Vision. Washington DC: National Academy of Sciences*, 308, 1-21.
- Millar, R. (2010). Practical work. *Good practice in science teaching: What research has to say*, 2, 108-134.
- National Academies of Sciences, Engineering, and Medicine (2015). Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts. *Washington, DC: The National Academies Press*. .
- Oliveira, H., & Bonito, J. (2023, May). Practical work in science education: a systematic literature review. In *Frontiers in Education* (Vol. 8, p. 1151641). Frontiers Media SA.
- Osborne, J. (2015). Practical work in science: Misunderstood and badly used. *School science review*, 96(357), 16-24.
- Rollnick, M. (2017). Learning about semi conductors for teaching—The role played by content knowledge in pedagogical content knowledge (PCK) development. *Research in Science Education*, 47(4), 833-868.
- Rollnick, M., Mundalano, F., & Booth, S. (2013). Concept maps as expressions of teachers' meaning-making while beginning to teach semiconductors. *Research in Science Education*, 43(4), 1435-1454.
- Sarabi, M. K., & Gafoor, K. A. (2018). Student Perception on Nature of Subjects: Impact on Difficulties in Learning High School Physics, Chemistry and Biology. *Online Submission*, 8(1), 42-55.
- Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on high students' academic achievement. *JOTSE*, 10(2), 199-215.
- Singh, B. V., Hugo, W., & Essack, S. (2013). What does Gravity, Density and Waves have to do with Pharmacy Education. *Unpublished PhD Thesis*. University of KwaZulu Natal.
- Walton, E., & Rusznyak, L. (2019). Developing standards for inclusive teaching in South Africa: A dilemma analysis. *Southern African Review of Education with Education with Production*, 25(1), 89-106.
- Xie, M. (2021). Enabling students' knowledge building in English classrooms in China: The role of teacher monologue. *Text & Talk*, 41(2), 261-285.
- Yu, D., Sun, Y., Liu, Y., & Li, Z. (2022). Study on Teaching System of Semiconductor Device Physics under Information Background. *Academic Journal of Science and Technology*, 2(1), 39-41.