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A case for project based learning to enact semantic waves: towards cumulative knowledge building

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ABSTRACT
First-year undergraduate curricula and their delivery should assist students in the transition from previous learning experiences to learning in higher education. However, the so-called articulation gap or discontinuity between secondary and higher education has been identified as a key structural curriculum problem for first-year success in South Africa and abroad. Valuable insights into this problem came from a recent study that drew on Legitimation Code Theory (LCT). Findings revealed an unexpectedly wide gap between the high school and the university biology curricula. The high school biology curriculum displays minimal movement between context-dependent, simpler meaning and relatively decontextualized, condensed meaning common in first-year biology. LCT Semantics was also found to be a valuable tool for restructuring curricula and pedagogy to intentionally enact semantic movement and thereby a more gradual transition for students from high school to university. This paper reports on an integrative first-year biology project aimed intentionally at taking students' concept knowledge through a wide contextual range, and repeatedly between less and more complex meaning. I reflect on how the project design steers students towards creating semantic movement during their presentations, thereby contributing to cumulative knowledge building and a more gradual transition towards first-year epistemological access.

KEYWORDS
Articulation gap; epistemological access; transition pedagogy; Legitimation Code Theory; semantics; project-based learning

Introduction

Moving into higher education is one of the most difficult academic challenges that many students will face in their lifetime. To make the transition into first-year undergraduate studies more gradual and attainable, Kift (2009) proposed a 'transition pedagogy' whereby first-year curricula and their delivery are explicitly aligned to support first-year students from their previous learning experiences, to the ways of teaching and learning in higher education. In this paper, we put the spotlight on the transition of students from school to first-year biology. The paper explores the approach of project-based learning as a means to assist in this transition by highlighting a specific project, introduced to enact semantic waves and therewith cumulative knowledge building during the learning activity. This project was firstly designed and then evaluated by drawing on Legitimation Code Theory (LCT) (Maton 2013, 2014a, 2014b).

Moving into first-year in higher education

An impressive body of research, practice and policy is available to enact effective efforts to enhance first-year persistence and success (Kinzie 2005; Lizzio 2006; Conley 2007; Briggs, Clark, and Hall 2012; Tinto 2012; Nelson 2014). However, despite these research insights, it seems that little has changed in practice

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with countless students finding this transition problematic. Vincent Tinto (2006–2007) recapitulates this situation as follows: 'Substantial gains in student retention have been hard to come by', and that 'a lot more needs to be done to translate the body of research into effective practice'. More effort should therefore be made to implement some theory into practice to improve first-year success.

In South Africa, institutions of higher education have also grappled with the quandary of first-year success for years. Evidence has shown that a significant fraction of school leavers are not prepared for studies in higher education, especially in the STEM fields (Case, Marshall, and Grayson 2013; Shay 2017). A report from the Council on Higher Education (CHE 2013) revealed a high attrition rate at first-year level, combined with a low overall completion percentage and even lower rate for completion in regulation time (Scott, Yeld, and Hendry 2007). One key structural curriculum problem identified to contribute significantly to this situation, is the so-called 'articulation gap' or discontinuity between secondary and higher education (Case, Marshall, and Grayson 2013; Shay, Wolff, and Clarence-Fincham 2016). This disconnect can be attributed to both poor preparation on the high school side, as well as weaknesses in teaching and learning in higher education. Case, Marshall, and Grayson (2013) therefore make the case that higher education in South Africa needs to develop curricula to 'teach the students we have, not the ones we wish we had' (Jones 1995). In other words, these curricula should contribute to bridging the gap and work with 'what first-year students bring with them' into undergraduate studies, irrespective of expectations or assumptions what these should be. Some studies suggested that to achieve this, the pace and content of curricula be adjusted (Engelbrecht, Harding, and Phiri 2010; Wolff 2010). Kift (2009) corroborate the view that first-year curricula be designed to explicitly support students in the transition from learning in school, to learning in higher education, over a period of time. Moreover, the term 'transition pedagogy' was therefore coined to encompass a broader view on curriculum, with the intentional design of teaching and learning that would address the world of current contemporary students. This approach further aims to navigate the wide range of competencies, as well as the cultural capital of new first-year students.

The Australian Learning and Teaching Council Fellowship Program has articulated a research-based 'transition pedagogy' (Nelson and Kift 2005). This is basically a guiding philosophy for intentional first-year curriculum design and support, with the aim of scaffolding the first-year learning experience for contemporary heterogeneous cohorts (Kift 2009). It identifies six first-year curriculum principles that promote first-year learning engagement, success and retention (Kift 2009):

- Transition: The curriculum and its delivery should be designed to be in line with the students' previous educational experiences. It should further mediate and support the transition as a process occurring over time.
- Diversity: The curriculum should accommodate student diversity and must be inclusive of all students. This factor often accompanies transition problems.
- Design: First-year curriculum design and delivery need to be learning-focused, explicit and relevant. It should also intentionally integrate and sequence knowledge skills and attitudes.
- Engagement: The first-year curriculum should enact an engaging and involving curriculum pedagogy, as well as active and collaborative learning (peer-to-peer and teacher-student).
- Assessment: The first-year curriculum should assist students in making the transition to assessment in higher education with an increase in complexity.
- Evaluation and monitoring. First-year curriculum design should be evidence-based and regularly amended after evaluation to improve student learning.

Project based learning

As lecturers, we all strive towards facilitating cumulative knowledge building for our students (Maton 2009, 2013). In this type of learning students would be able to build on their previous knowledge, make the connections between their new and past knowledge and transfer this knowledge across a range of contexts. Cumulative learning could therefore be a decisive factor in a transition pedagogy. One curricular and instructional model with the capacity to facilitate cumulative learning is project-based learning (PBL) (Lee et al. 2014). PBL is an inquiry-based instructional approach that is student-centred and also offers one approach to curriculum design and a transition pedagogy. The focus of PBL is to let students address or answer real-world problems or scenarios using concepts from the discipline, as well as other tools, experiences and technologies. According to research by the BIE (2013), PBL leads to students developing deep content knowledge, critical thinking and creativity, as well as communication skills in the process. Moreover, it has been found to create a 'contagious, creative energy' among the students and their lecturers. Interestingly, this approach is widely used in schooling systems, in contrast to higher education which has been more lecture driven for some time. Project-based learning lies within the constructivist learning theory and argues for alternative world views and 'it investigates and teaches their adaptivity'. However, foundational knowledge is still key to the learning process (Fűz-Kószó and Szabó 2013).

Essential criteria have been identified to qualify first-year projects for PBL as being 'rigorous and relevant' (Lee et al. 2014; BIE 2013). Firstly, the project needs to be a valid, real-world task, in other words, be authentic. In the second place, the project needs to be academically challenging. Thirdly, students need to collect information by active exploration, thus sustained inquiry. Fourthly, students have to apply their knowledge using higher performance attributes, including the analysis and organizing of their information, as well as collaborating and communicating with fellow students. Students also have to make adult connections in the process and must be able to take a number of decisions themselves, e.g. how to structure their project. Lastly, assessment and/or reflection practices must be a core part of the project. With the inclusion of some flexibility, student projects need to be carefully designed and supervised, as well as assessed to bring about optimal learning of subject content (Lee et al. 2014; BIE 2013; Fűz-Kószó and Szabó 2013).

The articulation gap in biology

A recent study has shed valuable light on the articulation gap specifically in biology by using Legitimation Code Theory (LCT), and specifically the Semantics dimension (Kelly-Laubscher and Luckett 2016). Findings revealed a surprisingly wide gap between the high school biology curriculum and the university curriculum in South Africa. More specifically, the study showed that the content of the school curriculum and text book was mostly less complex, with limited examples and applications from the real-world. In contrast, the first-year content was found to be significantly more complex in meaning and displayed a wide range for context dependence, from strongly contextualized (containing multiple references to real life examples, experiments and applications) to completely decontextualized meaning (abstract concepts). Thus, for first-year students, not only was the sudden increase in the level of condensed complexity, known as epistemological condensation (Maton 2013), but also the wide range between concrete and abstract meaning, often very arduous to navigate. The study concluded that numerous students struggle with this epistemological leap, especially those from previously disadvantaged educational backgrounds.

Legitimation code theory and this study

Legitimation Code Theory (LCT) is a social realist framework that offers a multidimensional conceptual toolkit to assess, but also shape practice (Maton 2013, 2014a, 2014b). Moreover, in pedagogy, the framework provides tools to evaluate, amend or design curricula to facilitate cumulative learning (Maton 2009). The five dimensions of LCT offer different concepts to analyse the underlying organizing principles of practices and then present these as legitimation codes. This study employs the Semantics dimension of LCT, which considers social fields of practice as semantic structures. In this case, the organizing principles are presented as semantic codes, comprising *semantic gravity* and *semantic density* (Figure 1).

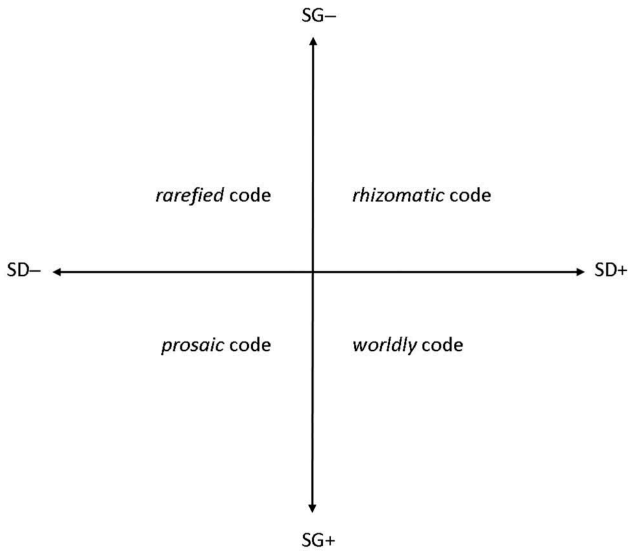


Figure 1. The Semantic plane used in Legitimation Code Theory (Maton 2014a). Semantic gravity (SG) is displayed on the vertical axis and semantic density (SD) on the horizontal axis.

Semantic gravity (SG) refers to the degree to which the meaning relates to a context. Semantic gravity can be stronger and weaker along a continuum of strengths. With stronger semantic gravity (SG+), the meaning is strongly tied to a context and the meaning would therefore be more concrete. Similarly, weaker semantic gravity (SG–) would imply more abstract or decontextualized meaning. In practice, semantic gravity can be strengthened by moving from more abstract meaning to more general, concrete, contextualized meaning and in the same way weakened by doing the opposite. In biology, referring to an abstract term such as 'the cystic fibrosis transmembrane conductance regulator (CFTR)' protein would indicate weaker semantic gravity and when referring to the disease, cystic fibrosis (real life example and stronger context), would imply stronger semantic gravity. Thus, in biology real-world applications of the concepts would strengthen semantic gravity. Also, for the purpose of this study, we regard more common examples and applications in the real-world as stronger semantic gravity than applications in the medical field for example, which represent a more limited context.

Semantic density (SD) is an indication of the complexity of meaning. Semantic density can also be stronger and weaker along a continuum of strengths. Stronger semantic density (SD+) would indicate more complex, condensed meaning, whereas weaker semantic density (SD–) implies more general, less complex, less condensed meaning. In practice, the semantic density can therefore also be dynamized by moving (strengthening and weakening) between complex, condensed meaning and simpler general meaning. In biology, when a term or concept is used, the meaning is usually relatively condense and complex. When the meaning is explained and unpacked using simpler terms, the semantic density is weakened in the process. To go back to the previous example, the term 'cystic fibrosis transmembrane conductance regulator (CFTR)' protein would indicate stronger semantic density since the meaning is condensed and very complex. Simply referring to the same protein as a transporter protein (more general meaning) would weaken the semantic density.

The two relations, semantic gravity and semantic density, and their relative strengths, form the axes of the *semantic plane* (SG+/–, SD+/–) (Figure 1), with the four *semantic codes* (Maton 2014a). The *rhizomatic code* (SG–, SD+) is where meaning is relatively context independent, but complex. In the *worldly code* (SG+, SD+), meaning is still complex but relatively context dependent and more concrete.

The *prosaic code* (SG+, SD−) represents meaning that is less complex and simpler, but context dependent. The *rarefied code* (SG−, SD−) is where meaning is relatively simple but context independent and thus more abstract. Practice can display code shifts with movement between more abstract and more contextualized meaning, as well as between simpler and more complex meaning (Maton 2014a).

In a previous study we have shown how pedagogy in biology should enact such shifts for cumulative learning to take place (Mouton and Archer 2018). We presented the example of membrane structure and function where the 'Fluid Mosaic Model' of a membrane would represent the rhizomatic code (SG−, SD+). The real life example of cystic fibrosis and how this condition affects the integrity of the membrane and thereby the life of the patient, represents the worldly code (SG+, SD+). When referring to all living organisms having cell membranes which make life itself possible, would fall into the prosaic code (SG+, SD−). The rarefied code (SG−, SD−) can be enacted by referring to cells having plasma membranes and eukaryotic cells having additional membranous organelles, dividing cells into distinct functional areas. In practice, we can analyse or plan shifts in semantic gravity and semantic density, thereby tracing or designing the *semantic profile* and an associated *semantic range* between the highest and lowest strengths. A semantic profile characterized by iterative upward and downward shifts in semantic gravity and semantic density enacts *semantic waves* (Maton 2013, 2014a). Thus, during semantic waves, meaning is lifted out of gravity by abstracting away from concrete meaning, and then brought back again to concrete and simpler meaning, thus the strengthening and weakening of both semantic gravity and semantic density. This brings about the decontextualization and recontextualization of knowledge over time, thereby leading to knowledge building in two directions (Maton 2014a).

The prevalence of semantic waves in student discourse has been shown to play a role in achievement (Maton 2013). Research revealed that high achieving student essays are characterized by a wider semantic range than that of low achieving essays, which often display semantic flat-lines (little or no movement between the simpler contextualized and more complex decontextualized meaning). However, it must be pointed out that this depends on the questions asked or the aims of a project. Georgiou's studies (2016) in physics education showed that students lacking experience in science (more novice learners) expressed a very limited gravity range in explanations, often remaining at the very concrete levels of stronger semantic gravity. Students with a stronger science background seem to understand that a wider semantic gravity range is needed to explain and answer certain questions. They also found that more proficient students understood which questions required a certain range for semantic gravity. However, less proficient students were found to often draw on explanations too weak in semantic gravity, thus reaching up the semantic gravity scale when not required, revealing their lack of discernment.

Extensive research of classroom practices in Australia, as well as in other countries, showed that the use of semantic waves enables cumulative learning (Maton 2013; Blackie 2014; Clarence 2017; Kirk 2017), a key aspect in 'connecting dots' of knowledge. Blackie (2014) argues that many lecturers (organic chemistry in her case) use terms and simply presume that students understand the broader scope of what is being said. Instead, lecturers should consciously and intentionally move between stronger and weaker semantic gravity, as well as between stronger and weaker semantic density to enact semantic waves in their teaching of such abstract discipline content. Clarence (2017) showed that LCT Semantics can be used by lecturers to understand how to facilitate cumulative knowledge building using semantic waves in a first-year law course. In the field of academic writing, Kirk (2017) demonstrated how students can be taught to use the concepts of semantic gravity and semantic gravity waves to understand what is valued and required in their writing assignments. Matruglio, Maton, and Martin (2013) used the interesting approach of temporality in classroom practice to enact semantic waves. From these studies it is evident that using the concepts of the Semantics dimension of LCT to enact semantic waves in classroom practice has vast potential to aid in narrowing the articulation gap between high school and undergraduate first-year curricula. In classroom practice, lecturers would for example reach back to discipline content from school but also stretch toward the new complex discipline content in recurrent cycles. In this type of classroom practice, knowledge is continuously transformed between relatively concrete, simpler meaning and more condensed decontextualized meaning, leading to the ability to build on previous knowledge and the transfer thereof into new contexts. Moreover, this tool would therefore be a valuable addition to developing a type of transition pedagogy.

In this paper, project-based learning is considered as part of a first-year biology curriculum and transition pedagogy, amended to enact semantic waves (Mouton and Archer 2018). The idea was to introduce a new project that would enact shifts between the semantic codes by immersing students in a range of real-world applications of the abstract biology concepts dealt with in class. This approach was expected to develop deep content knowledge and also widen students' knowledge about the wide range of real-world applications (more context and thus a wider range for semantic gravity) where the abstract concepts come into play (application), and also to steer them towards stronger complexity of meaning with regards to the biology concepts (stronger semantic density). The greater goal was therefore to facilitate a more gradual transition into the complexity of first-year biology using a more familiar background. The design, as well as outcomes of the project were put under the spotlight using the Semantics dimension of LCT. Firstly, the project was designed with the explicit aim to steer students towards a journey that would enact semantic movement of their biology content knowledge. Thereafter, the student presentations were analysed to evaluate whether the projects indeed took students through more than one of the quadrants on the semantic plane (shifts), thereby contributing to a wider contextualized background, to frame the abstract cell biology discipline knowledge.

Methodology

Designing the project

Evaluation and restructuring of an Extended Degree Programme (EDP) biology module (Mouton and Archer 2018), combined with the findings of the Kelly-Laubscher and Luckett study (2016), revealed the need to incorporate learning activities that would place and expand the conceptual cell biology knowledge of students within a wider range of contexts (real-life applications and examples). In terms of LCT Semantics, such an intervention needed to expand the range of semantic context (semantic gravity) of the students' conceptual cell biology knowledge, allowing students to 'connect more dots' (concepts and contexts) between biology concepts and 'real-world' examples, towards cumulative knowledge building.

A project-based approach was selected to allow active learning and participation (Kift 2009), and the project was carefully planned to be rigorous and relevant as set out by BIE in Lee et al. (2014). A considerable amount of time and effort went into the selection of a central theme for the project that would include different, yet related topics. The Semantics dimension of LCT was employed for the purpose of the project design. Firstly, the project theme had to have the capacity to widen the contextual knowledge of students for a rather abstract section of the curriculum on cell biology, thus the application of theoretical concepts knowledge to a range of real-world contexts. The instructions then had to be formulated in such a manner that the topic would lead the students to move between very concrete examples, including a considerable volume of simpler everyday knowledge, to more complex condensed, but still concrete meaning. The instructions then also had to direct students to move to the abstract cellular level as presented in the first-year biology curriculum. This section would be much more complex in meaning and move to greater abstraction in meaning. Thus, the selected project theme had to tacitly steer students towards movement between simpler contextualized and more complex, contextualized meaning, and then also towards complex decontextualized meaning, thereby enacting semantic waves and shifts across a minimum of three of the four semantic plane quadrants. This project was therefore intended to tacitly expose students to powerful theoretical concept knowledge, while also facilitating access into the inferred framework of norms, values and practices needed to make sense of the abstract content (Ellery 2017).

The anticipated project outcomes included student presentations that would enact movement on the semantic plane and therefore semantic profiles characterized by semantic waves. During this process, students would move between simpler contextualized meaning and more complex abstract meaning which would allow students to see more connections between the powerful abstract concept knowledge of the first-year biology curriculum and a world of context.

Project theme and instructions to students

Careful planning went into selecting a suitable encompassing theme for the student project that would allow for the type of learning intended (as explained in the previous section). The project theme eventually selected was: 'The power of poison'. After thorough research, it was evident that this theme would expose students to a wide range of substances (poisons and venoms) that affect living cells and had the capacity to paint a broad backdrop (real-world applications) for the abstract cell biology section of the curriculum. Contrasting the 'normal' functioning of cellular structures and processes against the poison induced disrupted structures and processes, allowed for inspiring student interest and engagement. The following phrase of Paracelsus was used with the theme to evoke the curiosity of the students: 'Poison is in everything and nothing is without poison. The dosage makes it either a poison or a remedy'. To create further interest, the project was introduced in phases, using three 'teasers', including the Paracelsus quote.

Students were instructed to form groups of three to four and had freedom to select their own group members. Each group then drew the name of a different poison. Topics included: cyanide, curare, venom of the Brazilian wandering spider, bullet ant venom, black mamba venom, scorpion venom, botulinum toxin, tetrodotoxin, alpha-amanitin, ricin, maitotoxin, VX nerve agent, polonium, batrachotoxin and bisphenol A (BPA). The project layout included instructions about specific points their research had to address such as the origins and background of the substance (real-world context), as well as detail on how the substance would disrupt the biology of affected cells (more complex abstract meaning). The 'normal' functioning of cells dealt with during class was thus contrasted against the disrupted mechanisms in affected cells.

All group members were expected to contribute to research on the assigned topic. Student groups then had to prepare a 10 to 12 minute PowerPoint presentation to present their research to the rest of the class and all group members were required to participate in the presentation. The presentations were followed by three to five minute question sessions. Non-presenting groups received score sheets (one per group) prior to the presentations and the groups were required to peer assess each presentation on the following aspects: Whether the presentation was interesting, capturing and presented with enthusiasm, whether the group was well prepared and the presentation well structured, and whether the presenting group displayed sufficient background knowledge about their topic. These group assessments were done after briefly discussing the presentation among the group. However, it must be emphasized at this point that this assessment was done with a rubric and not with a LCT approach.

The assessment sheet contained a separate section where students had to rate the presenting groups' account of the effect of the substance on cellular level and whether it was adequately explained (in such a way that they understood the effect). And finally, the score sheets also included an additional section where the assessing group had to write down a minimum of three aspects they had learnt from the presentation. Group members had to collaboratively decide what was learnt from each talk. These sections of the score sheets were then evaluated by the lecturer with regards to the level and depth of the contributions and marks were awarded accordingly.

The final project mark contributed significantly (approximately equal to one of the three semester tests) to the final achievement mark for the module. The final project mark consisted of the mark obtained for the group presentation, as well as a combined mark calculated from the set of peer assessments.

Participants

The participants in this study were the students registered for the Biology 146 module. This module forms part of the foundation phase year of an Extended Degree Programme (EDP). Students in this programme complete a normal three year degree over four years where the first year of study is spent on foundational modules. These modules intend to prepare students for mainstream degree-studies by focusing on conceptual development, as well as key academic skills necessary for future success. Moreover, this programme aims to broaden access to degree programmes for students who are from disadvantaged educational backgrounds and fall just short of the entry requirements for the mainstream degree programmes.

Data collection

Student presentations were recorded using Camtasia relay and converted to MP4 files. The video files were used to transcribe the presentations for analysis using the Semantics dimension of LCT. A translation device was composed for the Semantics analysis, including criteria for both semantic gravity and semantic density (Table 1). For each transcribed presentation, themes were identified across the slide show and rated for both these concepts to cumulatively reveal the semantic profile. Furthermore, the peer assessment sheets were used to construct an additional semantic profile for each group's assessment efforts, specifically for the written section that included the aspects they had learnt from the presentations.

A Google Form was set up to collect qualitative feedback from the Biology 146 students about the learning experience in class and particularly that of the project. Thirty of the 62 students participated in the questionnaire. Twenty-five of the participating students had biology as a school subject and five not. Apart from the questions about the project, questions were also included to gauge their perceptions and experiences of school versus first-year biology, and therefore included the following questions: 'Did school biology prepare you for first-year biology?', 'How is first-year biology different from school biology?' and 'How do the biology concepts differ from school to first-year?'

Table 1. Translation device for semantics analyses of the 'power of poison' student presentations, with examples from a presentation.

Concept	Indicators	Examples from presentation
SG–	Specialized abstract biological concepts: Molecular structures and functioning at molecular level (no context or examples).	'…. The X toxin has a light chain and a heavy chain. The heavy chain allows the protein to bind to and enter the neuron. As the heavy chain allows entry, the light chain works as a protease and cleaves the protein …'
	More general but still abstract biological concepts: Structures and functioning (no context or examples).	'….. X toxin interferes with the release of acetylcholine, which is an important neurotransmitter ….'
	Specialized examples/context of concepts, e.g. in medical field (limited context).	'…… by blocking the neurotransmitters, X toxin causes flaccid paralysis, which is one of its characteristics.'
SG+	Common examples of concepts in everyday real life (range of contexts and examples).	'Most people know X as a type of food poisoning that is contracted by eating infected products such as undercooked meats and other canned goods.'
SD+	Specialized technical terms.	'….. These Gram negative, anaerobes are rod-shaped and form endospores that enable them to stay dormant under unfavourable conditions …'
	Technical terms from the wider range of biological fields.	'…….X toxin affects the neuro-muscular junction which is the synapse between a neuron and a muscle cell.'
	Specialist, but more common terms and language.	'You get food-borne X when you ingest improperly preserved foods that have been contaminated with the bacterium.'
SD–	General everyday language.	'These bacteria are commonly found in soil across the world.'

Results

Generally, students reported that school biology laid a foundation for first-year biology, although most felt that the preparation was not adequate:

> '. . .we were thrown with information without any in depth explanations', 'School provided me with a basic idea of topics, whereas university provides a much more complex and deeper understanding of the concepts',

> '. . ..certain terms were familiar, but school biology is not as abstract as first-year biology'.

On the question of how school biology differs from first-year biology the majority reported that first-year biology content volume is significantly higher, the pace much faster and that the curriculum significantly more complex, in-depth and detailed in contrast with school biology:

> 'The workload in university is much more and a deeper understanding of the topics is required, whereas in school you could pass by understanding the basic concepts',

> 'The terms (concepts) are more abstract in first-year and contain more chemical properties. School biology is a lot simpler, the terms are not as abstract and the pace is slow'.

On the question about how biology concepts differ from school to first-year, these students captured the general trend of the responses very well:

> 'In school work we barely scratched the surface. There were a lot of things not fully explained due to the complexity of it and that made that there were lots of gaps in our bio knowledge. First-year is way more depth and far more interesting because we finally get more of the picture.'

> 'First-year biology we do everything in a great amount of detail and we learn how everything is interlinked. In high school we learnt the different concepts individually and could hardly see the way in which the concepts link and . . .. . .'

The vast majority of students responded that they learnt new concepts and context from the project and only two students reported that they felt that they did not benefit from the project. The theme of the project evoked substantial interest and students generally reported having learnt new concepts that they were able to link to context:

> 'It's very interesting and a nice topic for a project. The topic forces you to understand the concepts in a different context',

> 'We could recognize connections and see how biology relates to the real-world.'

> 'It was great! Learning biology through real life examples such as poison (which students are generally curious about), helped understand the concepts better. Choosing different types of poison kept the activity fun and interesting. Students were not confined to learning by themselves but learnt new facts from other groups and their team members.'

Students also reacted very positively to the idea of the presentation with peer assessment:

> 'I thought it was a great way of combining biology with a presentation as in a presentation you have to know what you are talking about along with the images. The images and diagrams helped to link concepts and helped with a better understanding.'

> 'I loved this project and also liked the idea of peer assessment. It forced people to really concentrate during the presentations and think of questions for themselves. I certainly learned a lot about other groups' poison and not only my own'.

The Semantics analyses of the student presentations were done by coding the transcripts of the student presentations. The translation device in Table 1 was used for coding the relative strengths for semantic gravity and semantic density throughout the presentations. Two typical semantic profiles are presented in Figures 2(a,b) and 3(a,b) which show a lower scoring, and the top achieving presentation. The data from these two presentations is presented in two ways, a wave graph and on the semantic plane. The wave graph shows the enactment of semantic waves for

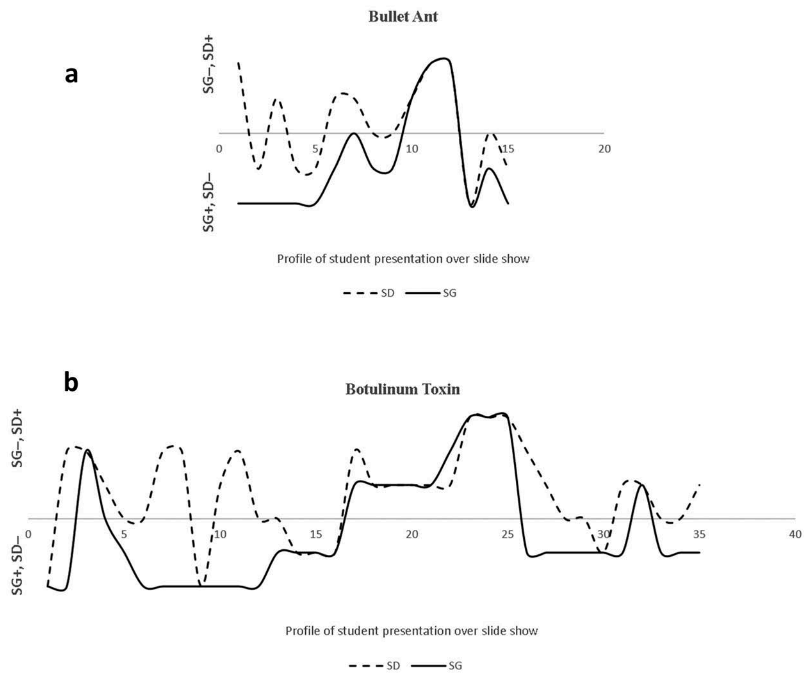
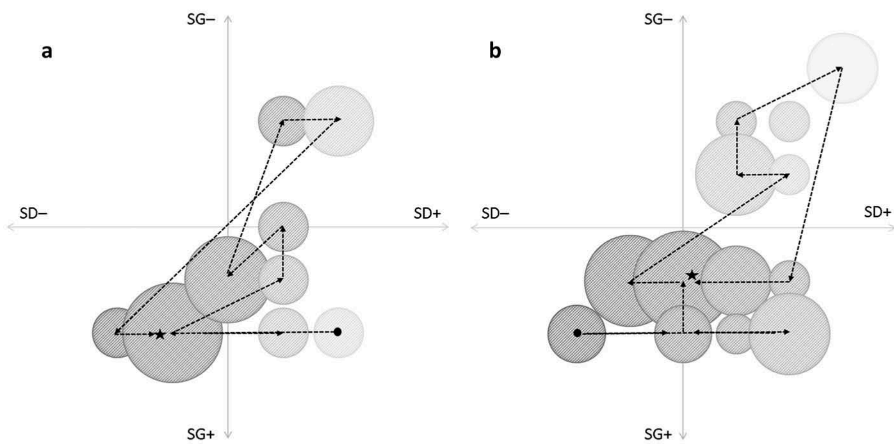


Figure 2. (a,b) The semantic profiles of two student presentations showing semantic waves for both semantic gravity and semantic density.

both semantic gravity and semantic density (Figure 2(a,b)), whereas semantic shifts and therewith the use of different types of knowledge are shown on the semantic plane (Figure 3(a,b)).

In general and throughout the presentations, the semantic profiles displayed movement for semantic gravity suggesting that the content of the presentations shifted between concrete and greater abstract meaning. As mentioned before, it was the intention of the project to encourage students to move between real-world contextualized biology knowledge and conceptual, complex biology knowledge to enable cumulative knowledge building. Presentations thus shifted between relatively stronger and weaker semantic gravity, thus shifts in context dependency and a wider



Figures 3. (a,b) The semantic plane profile of two student presentations. The dotted arrows indicate semantic shifts (a simplified version) on the Semantic plane. The dot represents the starting point and the star the end point. The sizes of the 'bubbles' are relative to the time spent.

semantic range in contrast to the module content which is relatively devoid of context and real-world examples. Moreover, all presentations also exhibited movement between simpler and more complex condensed meaning, implying movement between weaker and stronger semantic density (Figure 2(a,b)). Students were thus tacitly steered to applying the complex terms (SD+) of the module content in combination with simpler meanings (SD−) of the background information. When both semantic gravity and semantic density are considered concurrently, it is evident that semantic waves were enacted to varying degrees throughout the student presentations.

To illustrate semantic waves and shifts, two presentations will be presented in more detail, one of the lower scoring presentations, as well as the top achieving presentation:

Bullet ant venom presentation

From the semantic profile in Figure 2(a) it is clear that this presentation was timewise the shortest of all the presentations and these students did not elaborate sufficiently on the concepts of their topic, probably due to language constraints (English is not the home language of these students). Nevertheless, the presentation still displayed adequate movement (multiple waves) between simpler and more complex meaning which allowed these students to actively engage with the complex module content. Moreover, in terms of semantic gravity, the presentation started with concrete, contextualized meaning (SG+), shifted to much greater abstract meaning (SG−) and finally returned to concrete, contextualized meaning (SG+; Figure 2(a)).

As shown in Figure 3(a) (the semantic plane), these students opened by introducing their topic, the bullet ant, and then elaborated on the scientific classification, natural habitat and other interesting facts (not generally known) about the ants. At this point of the presentation, the meaning was still relatively concrete and varied in terms of complexity between simpler and more complex meaning (SG+, SD−/SG+, SD+). The students then shifted to more complex meaning by introducing the class to the scientific classification of the bullet ant, as well poneratoxin, the neuro-toxic peptide produced by these ants (SG+, SD+).

> 'The bullet ant produces a venom called poneratoxin. The sting from the bullet ant is ranked on level 4 on the Schmidt index because it is known as the most painful sting of any insect.'

They maintained the complex meaning associated with the toxin but then shifted to more abstract meaning by describing the molecular composition of the toxin and the effect of the toxin on cellular level (SG−, SD+).

> 'Poneratoxin contains 25 amino acid peptides which block the synaptic transmission, stimulates the smooth muscles and modulates the gating modes of the sodium ions. As you can see on this picture (points to diagram), this is the linear primary structure of poneratoxin. On Aa (points to diagram) one can see it comprises of two alpha-helixes.'

They concluded their presentation by shifting back to concrete, simpler meaning when discussing the victims and the extreme levels of pain associated with the stings of these ants (SG+, SD-).

> 'Ok, I am going to say more about the bullet ant venom. It got its name from the painful bite it inflicts on its victims. They are known for their terrifying stings and survivors says it feels like being shot….'

Thus, despite this presentation being fairly short and possibly too concise, the project design steered these students to enact semantic waves in their presentation and movement through three of the four quadrants on the semantic plane (Figure 3(a)).

Botulinum toxin presentation

This student presentation achieved the highest mark and the semantic profile is displayed in Figures 2(b) and 3(b). This group had the most detailed presentation but still managed to finish within the prescribed timeframe. They were able to 'pack' a substantial volume of information into their presentation, which consequently made significantly more Semantics coding possible. As the semantic profile in Figures 2(b) and 3(b) reveals, this presentation started with concrete meaning (SG+), but quickly shifted to greater abstract meaning (SG−) before returning to concrete meaning (SG+) and then slowly progressed towards abstraction again (SG−). They brought the meaning back to the concrete towards the end. In terms of complexity of meaning, this presentation commenced with simpler meaning, but thereafter constantly shifted between more complex condensed and simpler meaning throughout the presentation, thus enacting semantic waves.

During their presentation, the students commenced with simpler, concrete meaning by introducing their topic botulism, a type of food poisoning (SG+, SD−), and then moved to more complex meaning by explaining that this infection is caused by the bacterium, *Clostridium botulinum* (SG+, SD+). While maintaining relative complex meaning, they then shifted to more abstract meaning by describing the various types of botulinum toxins produced by these bacteria in terms of molecular structure (SG−, SD+).

> 'The botulinum toxin is broken down into seven neurotoxins which are antigenically and serologically distinct, but structurally similar.'

The presentation then shifted back to concrete meaning when they discussed a brief history, as well as current medical uses of the toxin (SG+, SD+/SG+, SD−).

> 'Van Ermengem, a professor of bacteriology at the University of Ghent, succeeded in isolating *Clostridium botulinum* from some pieces of ham that had poisoned people at a funeral in Belgium. He was credited for naming the toxin Bacillus Botulinus, derived from "botulus", which is the Latin word for sausage. So, why they used the Latin word for sausage because back in the day, it was seen as a sausage poison'.

However, the presentation then gradually moved to greater abstraction and complexity (SG−, SD+) and at its turning point, the students described in a very clear and visual manner how the poison causes paralysis of victims by blocking the exocytosis of neurotransmitters into the synaptic clefts, blocking signal transmission between motor neurons.

> '... the toxin has a light chain and a heavy chain. Let me explain the light chain and the heavy chain quickly. The heavy chain allows the protein to bind to and enter the neuron as you can see (student points to a diagram). As the heavy chain allows entry, the light chain, which is the smaller one (student points to a diagram), works as a protease and cleaves the proteins that allow the neurotransmitters to leave the cell. So, basically, it chops it up and makes it inactive.....'

Moreover, they explained this process with understanding in their own words. From this point further, they moved back to more concrete meaning by considering the symptoms of affected patients, as well as how these mechanisms have been harnessed by the medical and cosmetic industry, where the meaning was still relatively complex but contextualized within a real-world application (SG+, SD+).

> 'In 1940, type A of the botulinum toxin was purified and isolated in crystalline form and then in 1998, the FDA approved the toxin as a treatment for strabismus and hemi-facial spasms, and since then it has been approved for thirty more diseases.'

Thus, this presentation was the most informative, detailed and included the most comprehensive version of the events on cellular level, which also represented the strongest levels of complexity and abstraction of all the presentations. This group was therefore able to reach the widest semantic range, which is what the project aspired to accomplish, and the group therefore achieved the highest mark. It was further evident that the project design steered these students towards the enactment of semantic waves in their presentation (Figure 2(b)) and semantic shifts between three of the four quadrants on the semantic plane (Figure 3(b)) which is desirable for cumulative knowledge building.

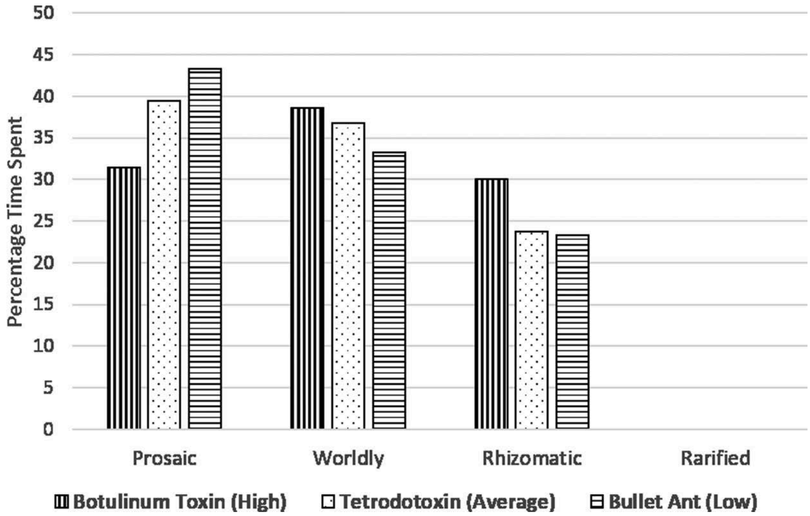


Figure 4. The relative percentage of total presentation time spent in the respective LCT semantics codes. The botulinum toxin presentation achieved 84% (top (high) scoring presentation), the tetrodotoxin presentation scored 72% (average scoring presentation) and the bullet ant presentation achieved 66% (low scoring presentation).

Student presentations were further evaluated by looking at the relative time spent in each of the quadrants on the semantic plane and three presentations were selected for comparison: the highest, an average and a lower achieving group (Figure 4). It was interesting to find that the top achieving presentation spent most of their time in the worldly code (SG+, SD+), but also a significant portion of the total time in the rhizomatic (SG−, SD+) and prosaic codes (SG+, SD−). Thus, most time was spent on complex contextualized meaning, with a fair amount on simpler concrete meaning and also complex abstract meaning. Moreover, this group spent by far the most time in the rhizomatic code (complex decontextualized meaning; SG−, SD+) when compared to the other presentations. Since the desired outcome of the project was for students to work with simpler to more complex meaning within real-world context, but also move to greater abstract meaning, this group probably achieved the best 'balance' between the different types of meaning required by this project. The average, as well as the lower achieving presentations spent most time in the prosaic code of simpler concrete meaning (SG+, SD−), followed by the worldly and rhizomatic codes, and could not quite deliver sufficient complex decontextualized meaning as was required by the outcomes.

Semantic analysis of student peer assessments

The peer assessment forms, more specifically the sections where the groups had to write a minimum of three aspects that they had learnt from the presentations were analysed, also using the translation device in Table 1. All the assessment comments of each group (assessing many other groups) were pooled for the Semantics analysis and the resulting profile therefore represented all the assessment comments of each group. Results showed that this activity made additional cumulative learning possible by yet again steering students towards movement through at least three of the quadrants on the semantic plane (Figure 5). Students' comments furthermore varied between simpler contextualized meaning and more complex, decontextualized meaning. Some groups were able and/or put in more effort to reach higher towards abstraction and complex meaning (SG+, SD+) in their written commentaries than others.

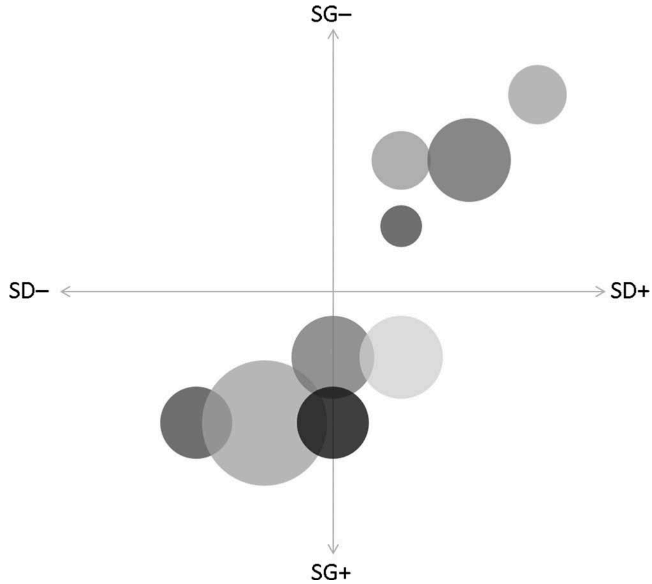


Figure 5. The semantic profile of a randomly selected peer assessment summary in which students had to indicate what they have learnt from each presentation. The sizes of the 'bubbles' are relative to the number of comments.

Discussion

A PBL approach was chosen to promote cumulative knowledge building in a first-year biology module. This intervention aimed to form part of a transition pedagogy approach to curriculum design (Kift 2009) and contribute to epistemological access for these students by helping to narrow the articulation gap in first-year biology. For this purpose, students had to research a real-world topic which was explicitly designed (using LCT Semantics and PBL principles) to steer them through varying strengths of complexity, as well as between very concrete (real-world applications) and abstract meaning within the cell biology content. In terms of the requirements of PBL (Lee et al. 2014), the project was authentic (real-world task), academically challenging, required active exploration and allowed students to structure their own research and presentation. Also, considering the LCT Semantics concepts, this implied shifting between the quadrants on the semantic plane, mostly between the prosaic, worldly and rhizomatic codes (in this specific case), to enact semantic waves (Maton 2013).

Semantic analysis of the student presentations showed that the semantic profiles varied in terms of depth and movement, as well as time spent in the respective semantic codes (Figures 2–4). Most groups spent a considerable amount of time between the simpler concrete, and also the more complex concrete meaning, as directed by the specific focus of the project, exploring the cell biology concepts within a wide range of real-world applications (contexts). However, the project outlines also required students to provide detailed accounts of how their substances affect victims on cellular level, representing abstract complex meaning (SG–, SD+). Results showed that all the presentations reached up into more complex, decontextualized meaning at least once during the talks when students explained the mechanisms and effects of the poisons on cellular level. Thus, in terms of LCT Semantics, most presentations spent the largest portions of time on simpler concrete meaning (prosaic code; SG+, SD–) and complex concrete meaning (worldly code; SG+, SD+) which was expected with the strong emphasis on the context. However, they then also shifted up into the rhizomatic code of complex abstract meaning (SG–, SD+) before returning to more concrete meaning towards the end. It was evident that the presentations indeed enacted semantic waves required for cumulative knowledge building which was the intention of the project to help bridge the articulation gap. Moreover, this study highlighted the affordance of the Semantics dimension of LCT as a design tool for learning activities. It was evident that its use in the careful planning of the project and ensuing instructions, succeeded in achieving the object of steering the students into enacting semantic waves during their presentations (Figure 2(a,b)).

In general, the semantic profiles of the student presentations showed regular shifts in semantic density throughout the presentations. Overall, students shifted almost rhythmically between less complex and more complex meaning, thus weaker and stronger semantic density (Figure 2(a,b)). This was often done by elaborating on complex meaning and concepts using simpler terms before proceeding, for example:

> '... the toxin has a light chain and a heavy chain. Let me explain the light chain and the heavy chain quickly. The heavy chain allows the protein to bind to and enter the neuron as you can see (student points to a diagram). As the heavy chain allows entry, the light chain, which is the smaller one (student points to a diagram), works as a protease and cleaves the proteins that allow the neurotransmitters to leave the cell. So, basically, it chops it up and makes it inactive.....'

In this example, the student presentation showed shifts in the complexity of meaning, while remaining in the abstract, rhizomatic code. It was my impression that students are probably more inclined to use shifts in semantic density (enacting semantic waves) when explaining complex meaning to their peers, in contrast to many lecturers. Students most probably need to explain complex meaning in such a way that they make sense of the meaning themselves using considerably more detail, and then replicate this when elucidating complex meaning to their peers, before proceeding to the next concept (complex meaning). It is therefore conceivable that students learn considerably more when listening to these explanations, than from 'normal' formal lecturing, especially when a lecturer is not mindful of the need for enacting semantic waves. Moreover, in combination with additional mindful input from the lecturer to clarify any misunderstandings following student presentations, the most effective learning likely occurs with this type of assisted peer learning. Moreover, in terms of PBL, this project was student-centred with guidance from the lecturer.

An interesting pattern emerged from the semantic profiles of the student presentations with regard to semantic gravity (Figure 2(a,b)). In general, student presentations showed less and smaller waves for semantic gravity during the first part of the presentations, where a considerable period of time was spent in contextual concrete meaning. This trend was expected since the project design and theme directed them to first introduce the source of their poisons where meaning was strongly contextualized in real-world applications. The smaller waves in the 'run-up' were the result of the presentations moving between more everyday concrete meaning and more specialized concrete meaning, still relatively strongly tied to the context. However, after this 'priming period', all presentations then shifted up into the rhizomatic code of decontextualized abstract meaning, by discussing the effects of the poison on particular structures and mechanisms in cells. As also illustrated by the previous example, this leap to abstract meaning, generated the 'big wave' for semantic gravity (SG−) seen on the semantic profiles. This gave the impression of students initially 'pump priming' the way to lay a sound foundation before making the 'big leap' up into abstraction, and eventually returning to more familiar concrete meaning towards the end. The semantic waves observed for both semantic gravity and semantic density in this study thus involved the weaving together of different types of knowledge or semantic codes: simpler concrete meaning, more complex concrete meaning and complex decontextualized meaning (Maton 2013). This project thus allowed for a set of abstract biological concepts to be explored in a wide range of real-world applications. Maton's research (2013, 2014a, 2014b) showed that the enactment of such semantic waves is key to cumulative knowledge building and this project's aim was therefore to steer students through these different types of knowledge using a central theme. Hence, cumulative learning empowers 'the recontextualization of knowledge through time and space' (Maton 2013).

The prevalence of semantic waves in student discourse has been shown to play a role in achievement (Maton 2013). Interestingly, this study also revealed that better achieving groups displayed a wider semantic range and showed a better understanding of the range that was required by the project to achieve good marks. In this case, reaching high up the semantic scale towards abstract meaning (in the rhizomatic code; SG−, SD+) was required for adequate explanations of the effects on cells. The top achieving group was able to accomplish this best and displayed very good understanding of the very complex decontextualized meaning on cellular level (Figures 2(b) and 3(b)). This group spent a significant portion of the presentation time, elucidating the cellular events in the rhizomatic code (Figures 3(b) and 4). Figure 4 shows the relative percentage of the presentation time spent in the respective semantic codes. It is evident that the top achieving group spent significantly more time in the rhizomatic code of stronger complexity and abstractness, as well as the worldly code of stronger complexity but more concrete meaning than the other groups presented in the graph. The lowest achieving group spent most of their time in the prosaic code of simpler concrete meaning. A randomly selected moderate achieving group presentation included in Figure 4, displays a similar profile to that of the lowest achieving presentation, although in their case, the longer time spent in the worldly code seemed to have made a difference for achievement. This project envisaged for students to move through at least three of the semantic codes or quadrants on the semantic plane, although one of the main requirements was a detailed explanation of events on cellular level (complex and abstract meaning in the rhizomatic code). It therefore appears as if the top achieving group was able to navigate this requirement best, and balanced this aspect very efficiently with the rest of their presentation, falling into the other two semantic plane quadrants. In contrast, the lowest achieving group was not able to spend adequate time in complex abstract meaning. Interestingly, the average group fell between these two groups in all aspects. This corroborates again what Georgiou (2016) found in her studies, that stronger students understand that a wider semantic gravity range is needed to explain and answer certain questions. Moreover, considering that the assessments were done using a rubric (by peers and the lecturer, not using LCT Semantics), it is noteworthy to observe that the presentations with ‘poorer profiles’ (less semantic shifts across the quadrants and less time spent in the rhizomatic code) indeed also attained lower marks. This corroborates Maton’s (2013) findings and suggests that even the students themselves, although subconsciously, value the enactment of semantic waves.

The peer assessment strategy was very effective in engaging students with their peers’ presentations. Although a small minority, there were students who saw this as an opportunity not to come to class even when being penalized for not contributing to the assessments. Despite this, the semantic analysis of the ‘what we have learnt’ sections showed that the project enacted semantic movement through three quadrants even for this part of the project. This is a significant finding, since listening to the presentations about the other poisons was meant to contribute greatly towards the main aim of building knowledge of real-world applications of these students with regards to the biology concepts dealt with in class. The majority of students found this way of learning fun and interesting, and reported that it forced them to think about the concepts and what questions to ask. Since, assessment and/or reflection practices is a core part of PBL, this is a crucial element of the project design towards the greater goal.

The Power of Poison group project facilitated understanding of abstract cell biology concepts across a range of real-world applications (contexts), as set out by the project outline and design. Students reported being able to see how concepts are linked and how these concepts link to the ‘real-world’. This study therefore firstly showed that LCT Semantics is an extremely valuable tool for designing and evaluating learning opportunities as part of curricula. And secondly, that purposefully designed PBL can facilitate the enactment of semantic waves in student learning. All student presentations enacted semantic waves to some extent, presenting the transformation of knowledge between simpler context dependent meaning and complex decontextualized meaning. According to research, this profile will ultimately lead to cumulative knowledge building (Maton 2013). Case, Marshall, and Grayson (2013; Jones 1995) argue that ‘we must teach the students we have and not the ones we wish we had’ and to address this, will require mindful intent in practice. Kift (2009) made a case for a 'transition pedagogy' that would support first-year students from previous learning experiences to learning in higher education, that is learning-focused, explicit and relevant, student centred, collaborative and engaging. I believe that pedagogy that includes thoughtfully designed learning activities to facilitate learning in the new environment of university, but also reach back to previous learning experiences through semantic shifts, may play a valuable role in such transition curricula. PBL with all its facets, may be a valuable element of such a transition pedagogy, by building discipline knowledge while developing a host of other attributes, and in doing so, help to narrow the articulation gap between high school and first-year in higher education. Finally, the Semantics dimension of LCT presents an exceptionally valuable design and evaluation tool to enact semantic waves in practice, thereby making it possible for first-year students to build new knowledge structures on the foundations of their existing knowledge.

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