A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education

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At 46 years of age, I am the first in my immediate family to have enrolled and submitted a Masters dissertation. I carry with me the dreams of generations before me who were not afforded the opportunity for education but who most definitely had the potential to have achieved educational qualifications. For me as for many others, I understand that education broadens your perspective on how you view the world. I also appreciate that education is not restricted to classrooms but is championed by a willingness to learn wherever and whenever that might be.

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Abstract

Angular motion is a foundational concept in physiotherapy, applied when measuring joint range of motion (rom) in assessment and treatment of patients. Accordingly, first-year physiotherapy students are commonly taught rom measurement skills in their applied Physiotherapy course and are introduced to the concept of angular motion in their Physics course where their learning is primarily assessed through problem-solving. However, studies of student learning of angular motion show that while students can solve problems, they do not always have the necessary conceptual understanding to use their procedures appropriately and flexibly in other disciplines. Physics education researchers also demonstrate that accessing, learning, and communicating the conceptual and procedural knowledge involves using the affordances of multimodal language.

Thus, a promising line of inquiry is how lecturers use the affordances of multimodal language in pedagogy to create opportunities for students to develop both conceptual and procedural understanding. My study focuses on a lecturer's pedagogy for the concept of angular motion in a Physics course for first year physiotherapy students at a South African university. Specifically, I use a multimodal social semiotic perspective to describe what and how she uses the affordances of multimodal language − verbal talk, written text, images, symbols and symbolic equations, gestures, and objects − to give presentational, organisational and orientational meanings. I also explain her pedagogical choices in the meaning-making process. In this focused ethnographic study, I observed lecture recordings to produce data on the lecturer's pedagogy. A subsequent semi-structured interview with the lecturer was analysed to understand the lecturer's choices.

The multimodal social semiotic analysis shows that the lecturer organised her pedagogy to develop both conceptual and procedural meaning, while also relating these meanings to problem-solving, and to orientate students to the relevance of angular motion in physiotherapy. This organization was informed by her comprehensive understanding of the physics content, and its relation to the Physiotherapy course and physiotherapy practice, and the experiences and resources of the students in the class. Evident in her pedagogy was a pattern of starting with a focus on conceptual meaning using verbal talk, images, and

gestures, following which she integrated symbols and symbolic equations which functioned as a link to focussing on procedural meaning as applied in problem-solving.

This study contributes to existing physics and physiotherapy education research, an in-depth description and explanation of a lecturer's motivated, contextualised use of multimodal language to give meaning to the physics of angular motion for physiotherapy. These learnings and the multimodal social semiotic tools by which they were produced can be put to work in education development practice with disciplinary lecturers. Specifically, they serve to make explicit the affordances of various language modes for communicating particular conceptual and procedural meanings as a relevant for physiotherapy for planning pedagogy.

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Chapter 1: Background and Purpose

1.1 Introduction to the study and dissertation

Angular motion is a foundational concept in physiotherapy, applied when measuring joint range of motion (rom) in the assessment and treatment of patients. Accordingly, first-year physiotherapy students are taught the skill of measuring rom in their Applied Physiotherapy course and are introduced to the concept of angular motion in their Physics course where their learning is primarily assessed through problem-solving. Studies investigating students' understanding of angular motion show that while students can solve problems, they do not always have the necessary conceptual understanding that informs the problems they are solving and so rely heavily on procedural understanding. However, having the necessary conceptual understanding is important to be able to use their procedural understanding to flexibly solve problems in different contexts. Consequently, physics education research foregrounds the importance of pedagogy for developing students' conceptual *and* procedural understanding.

Accessing, learning, and communicating the necessary conceptual and procedural knowledge involves using the affordances of multimodal language. Multimodal language includes verbal talk, written text, images, symbols and symbolic equations, gesture, and objects. In this regard, a promising line of inquiry is how lecturers use the affordances of multimodal language in pedagogy to create opportunities for students to develop both conceptual and procedural understanding. My study focuses on a lecturer's pedagogy for the concept of angular motion in a Physics course for first year physiotherapy students at a South African university (henceforth referred to as the/my university/institution). Specifically, I describe what and how she uses multimodal language to give meaning to the concept and explain her pedagogical choices in the meaning-making process.

In this introductory chapter, I first provide an overview of the Physiotherapy programme in which the study is located (section 1.2) and consider the difficulties with learning physics concepts from the perspectives of university physics lecturers and students. I locate this concern in the wider debates about student difficulties with learning science in South Africa. Next, (1.3), I explain how angular motion is relevant to physiotherapy, and position myself as a physiotherapist and part-time lecturer within the context of the study. This allows me to locate my observations of student difficulties with angular motion both in the Physiotherapy and Physics courses in wider debates on this at my university and in the literature. I then describe the relevance of multimodal language for communicating disciplinary meaning in physics and related sciences (1.4). After presenting the problem statement (1.5), I present the aim and research questions related to this study and then outline the scope (1.6) and significance of the study (1.7). Lastly, I explain how the dissertation is organised.

1.2 The physiotherapy programme

To qualify as a physiotherapist in South Africa, one must complete a Bachelor of Science degree in Physiotherapy at a university. The Health Professions Council of South Africa (HPCSA) prescribes the undergraduate training requirements for physiotherapists at South African universities (HPCSA 2020). Besides the physiotherapy disciplinary courses, the curriculum includes science-based courses such as Anatomy, Physiology, and Biosciences. Biosciences includes Chemistry, Physics, and Biomechanics courses. This study is located in the Physics course of the larger Biosciences course at an English-medium university in South Africa (further discussed in 3.2.2).

The size of the first-year physiotherapy cohort at the university ranges between 45 and 65 students. Most students completed schooling (grade 12) the year before starting their studies in the Physiotherapy programme. Admission to the Physiotherapy programme considers the students' performance in high school Mathematics, Physical Science or Life Science. There are a combination of students in the class who speak English as either a first or an additional language. Students are from diverse schooling and socio-economic backgrounds. It is well established that during the apartheid regime, formerly abolished in 1994, the South African education system was structured to provide unequal educational opportunities for different named race groups with inequitable access to science and mathematics disciplines. The consequences thereof are still experienced in the educational system, through a complex interplay of race, socio-economics, language, and geography (Spaull 2019; Jansen 2019).

The institution has implemented policies to ensure that students who are disadvantaged by persistent inequities in the schooling system are afforded opportunities to be admitted into health sciences programmes at the university (Hartman et al. 2012; Amosun et al. 2018). Ige et al. (2017) report that there is an awareness among lecturers that students admitted at the institution into programmes such as Physiotherapy, who come from under-resourced schools might not necessarily have the entry level science knowledge and quantitative skills to succeed at tertiary level education.

It is also well established that, in South Africa, many first-year university students – with a range of schooling experiences and backgrounds – who enrol for science- or mathematics-based courses find these challenging (Kizito et al. 2016; Makgato 2007; Linder et al. 2014; Case et al. 2013). Bray and Williams (2020) report that physics lecturers identified that students experience challenges with mathematics and solving complicated equations, as well as with conceptual understanding in mathematics and relating the mathematics concepts to the physics. Both student and lecturer participants concurred that their own experience of the quality of the physics teaching in high school contributed to their perception of the difficulty of physics. These findings concur with Ige et al. (2017). Engelbrecht et al. (2009), who investigated engineering students' understanding in a Mathematics course, explain that students can solve equations procedurally but often lack the relevant conceptual understanding.

In my study, I adopt the definitions for conceptual and procedural understanding from Hiebert (2013). Conceptual understanding is "…knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information" (Hiebert 2013, p. 3). Procedural understanding has two components: firstly, understanding the symbols (which represent concepts) in equations, and secondly, knowing the "rules" or steps to follow in completing the tasks (Hiebert 2013, p. 6). This means that procedural understanding is underpinned by conceptual understanding. The particular concepts and procedures related to my study are explained in section 3.2.2, 3.2.3, and Figure 3.3.

1.3 Locating angular motion in physiotherapy education and practice

Physiotherapy is a profession that aims to ensure that people lead healthy lifestyles by focusing on the prevention of illness and disability. It also aims to restore physical function that is compromised by illness, trauma, or injuries. I am a physiotherapist and a part-time university lecturer. I ventured into teaching after working clinically for many years. I first started engaging with students as a clinician, and was often concerned about why there appeared to be a disconnect between what students learned in class and how they understood its relevance and clinical application.

Of relevance to my concern is that, as part of the undergraduate physiotherapy curriculum in this study, students are introduced to the concept of joint rom in their Physiotherapy course while the scientific principles underlying rom are taught in the Physics course. As later explained in 3.2.3, in Physics students are taught about the kinematics of angular motion, which refers to the rotation of a rigid body about a fixed axis. In the human body, the limbs can be modelled as rigid bodies rotating about the joints, which are the fixed axes. This movement occurs due to the composite interaction of muscles on the lever which, in the case of the human skeleton, is a long bone (Levangie 2011). A typical problem that students might be expected to answer in the Physics course is, “A patient can flex their elbow over a range of 120°. What is the equivalent angular displacement of the forearm?”. Then, in the Physiotherapy course, which builds on the Physics course, students are taught the skill of measuring joint rom, using a tool called a goniometer.

When lecturing about joint rom and its measurement as a lecturer, I observed that students often used the goniometer incorrectly or recorded the angular displacement of the limb incorrectly. Studies have shown that the incorrect application of measurement techniques by experts and students affects the validity and reliability of the measurement (Brosseau et al. 1997; Unver 2009).

Informal discussions with the physics lecturer prior to my study suggested that students struggle to understand the concept of angular motion. She observed this in the application of incorrect symbolic equations (applying linear equations rather than angular equations where relevant). Student interviews that informed the specific focus of the research reported in this dissertation (4.1) pointed to students' challenges related to angular motion, such as their understanding of concepts such as ratios and tangents, mathematical procedures such as unit conversion. A student, whose first language is not English, explained that he found the science terminology difficult at times. As discussed in section 2.2.2, similar challenges have also been reported in physics education research on students' difficulties with kinematics (e.g., Mashood & Singh 2012; Mutsvangwa 2020; Trowbridge & McDermott 1981).

For a clinician physiotherapist, understanding angular motion in relation to movements at joints is key to problem-solving in the context of patient care. Physiotherapy education research argues for the importance of physiotherapy students, as future clinicians, relating their conceptual and procedural understanding to contexts relevant to practice (e.g., Ingerman et al. 2007; Rayner 2005). This research does not, however, focus specifically on the concept of angular motion. Furthermore, my literature review did not yield physiotherapy education research focusing specifically on pedagogy that creates opportunities for students to make the connections between physics concepts and physiotherapy practice (2.1.2).

1.4 Multimodality in physics teaching and learning and its relevance in enhancing physiotherapy practice

The use of multimodal language (that is, verbal talk, written text, gestures, images, symbols and symbolic equations, and objects and so forth, defined in detail in 2.2.4) for communicating the meaning of concepts or procedures is recognised in physiotherapy education. For example, simulations using technology, manikins, or trained patients are commonly employed to teach students specific clinical skills (e.g., Blackford et al.2015; Gough 2016; Miller et al. 2018). There is also a growing body of research on the affordance of digitally-augmented reality to develop students' understanding of concepts or to learn procedures (e.g., Da Silva et al 2021; Cavalcanti et al. 2019; Hoang et al 2017). These studies, however, do not specifically adopt a social semiotic perspective of language as central to disciplinary meaning-making, nor is there a focus on multimodal language for angular motion.

In contrast to the reviewed physiotherapy literature, the central role of multimodal language for meaning-making has been emphasised in physics education research. Linder et al. (2014) argue from a social semiotics perspective that university physics graduates need to develop disciplinary literacy, so that they can engage proficiently and fluently with a range of language modes relevant to their discipline. The understanding of concepts and procedures, and the ways of knowing and doing in physics, are constructed through multiple modes, with each mode contributing a particular aspect of meaning (Airey & Linder 2009). Lecturers in a study by Bray and Williams (2020) stated that physics students need to engage with multimodal language such as drawings, symbols, and equations for meaning-making in physics, but they find this challenging. Also focusing on language, Sherin (2001) asserts that it is important for students to have conceptual understanding of the symbols used in symbolic equations when solving problems procedurally.

Given the centrality of multimodal language for accessing, learning, and communicating disciplinary knowledge, how lecturers use multimodal language in pedagogy is an important consideration (Gaigher et al. 2006; Jewitt 2008). Detailed studies using a multimodal social semiotic perspective show that disciplinary-specific conceptual and procedural meanings are communicated by lecturers using the affordances of various language modes individually and together (e.g. Fredlund et al. 2015; Jaipal 2010; Le Roux & Kloot 2020; Tang et al. 2016). This argument on the value of multimodal language in learning science is elaborated on in section 2.1.3.

1.5 Problem statement

Angular motion is an important concept that students learn as part of a Physics course in the undergraduate physiotherapy curriculum. Studies in the South African context claim that not all school students are well prepared for university science and mathematics. Physics education research identifies students' poor conceptual understanding of angular motion, and my observations and discussions at the university point to physiotherapy students' difficulties with this concept. The need for physiotherapy students to better apply their physics understanding in Physiotherapy courses and to clinical practice in the future, is recognised. Multimodal language is identified as central to communicating, accessing, and learning disciplinary meanings in physics (Linder et al. 2014; Fredlund et al. 2015).

There is therefore a need to study what and how a physics lecturer uses multimodal language to create opportunities for physiotherapy students to learn the conceptual and procedural knowledge for angular motion.

1.6 The aim of my study

The aim of this study is to explore a physics lecturer's pedagogy for the physics concept of angular motion in physiotherapy education. I do this from a social semiotic perspective that recognises the centrality of multimodal language – verbal talk, written text, images, graphs, symbols, gestures, and objects – for disciplinary meaning-making. This theoretical perspective is productive for studying a lecturers' *contextualised, motivated* use of multimodal language in *pedagogy* to give meaning to the v*alued conceptual and procedural knowledge* of angular motion required by *physiotherapy* students as future professionals.

This aim will be achieved by answering the following research questions:

1. How does the lecturer use multimodal language in a lecture to give meanings to the physics concept of angular motion?
2. What motivated the lecturer's choice of certain multimodal language in the design of the teaching of the physics concept of angular motion?

This study focuses solely on the lecturer's pedagogy for the concept of angular motion in the context of the Physics course for first-year physiotherapy students. The aim of this study is to describe and explain the lecturer's pedagogy. It does not aim to evaluate the lecturer's practice.

1.7 Significance of the study

This study is significant because understanding the lecturer's pedagogy as well as her choices within context will provide research-based insights into what opportunities lecturers at the university may create for developing conceptual and procedural understanding of angular motion for physiotherapy students. The results will also inform my own lecturing practice and research-based education development practice with lecturers. In addition, since the problem to which the study responds is identified in both physics and physiotherapy education research, results focusing on *lecture pedagogy* have the potential to contribute to current debates in these fields.

1.8 Conclusion

Having now provided a background to the study, in Chapter 2 I further motivate and locate my study by providing a more detailed discussion of the literature first discussed in Chapter 1. In addition to the empirical literature, I present literature explaining the social semiotic theoretical framework for this study, and the focus on multimodality and its role in meaning-making in physics. In Chapter 3, I introduce the research design and context of the classroom. This contextual description includes a detailed overview of the angular motion module and the content explored in this study. In Chapter 4, I present the methods of data collection, production, and analysis, followed by the ethical and validity considerations of the study. In Chapter 5, I present the analysis of the results. In Chapter 6, I present the discussion of the results, recommendations for practice and further research, and the conclusion.

Chapter 2: Literature Review and Theoretical Framework

2.1 Introduction

I begin this chapter with a review of the concept of angular motion and its relevance to physiotherapy (2.2.1.). Then, locating this concept in the Physics course where it is taught, I present literature on the importance of contextualising the conceptual and procedural understanding developed in physics within the context of physiotherapy (2.2.2). Next, I discuss physics education research on teaching and learning of angular motion and other physics concepts, and the importance of multimodal language in teaching and learning (2.2.3). In section 2.3, I describe the multimodal social semiotic theoretical framework for my study (2.3.1) and the modes and their affordances relevant to my study (2.3.2).

2.2 Literature Review

2.2.1 Physiotherapy and angular motion

Movement at most human joints is angular in nature as body segments rotate around joints of articulation (Knudson 2007). Therefore the understanding of the physics concepts related to angular kinematics is important for physiotherapy practice, and measuring joint rom is a key clinical skill (Keogh et al. 2019). A goniometer (explained in 1.3), is generally used in clinical practice and physiotherapy training when teaching students about measuring joint rom (Milanese et al. 2014). Competency in measurement must be accompanied by an understanding of underpinning angular motion concepts and procedures. This informs the analysis of movement in determining the cause of any shortfall in the joint rom.

Several studies assess the reliability and validity of the joint rom measurement technique of students and clinicians at different joints and using different kinds of goniometers (e.g. Keogh et al. 2019; Milanese et al. 2014; Rome & Cowieson 1996). Other studies evaluate the effectiveness of clinical interventions by comparing the measurement of joint rom pre- and post- clinical intervention (e.g. Allwood & Ahlsén 2015; Hall 1996; Su et al. 2017; van Baar et al. 2001). Although these studies offer insights into different goniometers and their accuracy in determining the effectiveness of a clinical intervention, my literature review has not yielded studies in the field of physiotherapy education that explore students' understanding of the underpinning concepts of angular motion in relation to goniometry technique or clinical interventions related to joint movement, nor the pedagogy for these concepts, with the latter being the focus of my study.

2.2.2 Conceptual and procedural understanding of physics concepts for physiotherapy learning

As noted (1.2), in undergraduate physiotherapy programmes in South Africa, physics content is a standard inclusion in the curriculum and is taught in Physics courses. Thus, concepts and procedures taught in a physics course need to be contextualised by the lecturer so that students can understand how they apply in the context of clinical problem-solving in physiotherapy practice (Whitelegg & Perry 1999).

Arguments about the importance of contextualising physics knowledge in physiotherapy, and examples of how this can be done have been published (Ingerman et al. 2007; Parker 1993; Whitelegg & Perry 1999). Whitelegg and Perry (1999) suggest that contextualising physics learning in physiotherapy contexts can improve student motivation to engage with learning physics content. Kember et al. (2008) investigated what motivated undergraduate students to learn in their programmes of study, including professional degree programmes such as Occupational Therapy, Engineering, and Pharmacy. Students shared that early in their studies they had a limited understanding of the profession and could not see the relevance of science-based courses, such as Anatomy and Physiology. This lack of understanding of the relevance of the science subjects, the authors argue, prompted students to learn in order to pass the assessments, which means that students might focus on the procedural and less on the conceptual understanding. Like Whitelegg and Perry (1999), Kember et al., (2008) argue that student motivation to learn would have been improved if they understood the relevance of science-based content in their professional degrees.

Ingerman et al. (2007) argue for the contextualisation of physics and share how this might be operationalised within Physiotherapy curricula. They describe a new “metacognitivelyorientated physics curriculum” (p. 169) that they created for their undergraduate Physiotherapy programme at a South African university. This curriculum focused on “conceptual learning and coherence” of physics content and developing students' ability to relate the reasoning and knowledge of physics to the context of everyday life. Rennie and Parker (1993) explain that contextualising the physics concepts in everyday phenomena provides a model for thinking about how the physics relates to contextual examples.

Similarly, an Australian university offering a physiotherapy undergraduate programme contextualises physics in the curriculum by integrating relevant physiotherapy problems into the Physics course assessments (Rayner, 2005). In teaching practice, physics concepts are analysed and applied to clinical physiotherapy interventions, such as therapeutic ultrasound that physiotherapists use as a treatment technique. This approach, Rayner (2005) argues, encouraged physiotherapy students to see the relevance of the conceptual and procedural learning in their Physics course and how it is applicable to the context of professional practice.

Collectively, this literature points to the need for physics lecturers to create opportunities for students to develop the necessary understanding of concepts and procedures that are contextualised in the physiotherapy curriculum and practice. This contribution is relevant when considering concepts such as angular motion in my study, as this approach to curriculum foregrounds the importance of conceptual understanding and encourages students to use this understanding in the context of problem-solving in clinical physiotherapy practice. My study aims to explore how, through multimodal language, the lecturer creates opportunities for students to contextualise what they learn about angular motion in physics to physiotherapy.

2.2.3 The teaching and learning of the concept of angular motion

Most of the students in the first-year physiotherapy cohort at the university completed their schooling the year before, with some students having completed high school Physical Sciences, the curriculum for which includes the concept of linear motion. However, as noted (1.2), performance in school Mathematics and Physical Science is generally considered poor preparation for university study (Hartman et al. 2012; Ige et al, 2017).

Linear motion is also taught in the Physics course for physiotherapy students in my study. Physics education research has focused on student understanding of linear motion (e.g Dewi 2019; Kim & Pak 2002; Sutopo 2014), but my review suggests that very little research has been conducted on students' understanding of rotational motion.

In response to this gap, Mashood and Vijay (2012) devised an inventory to assess high school students' and teachers' (all of whom had postgraduate degrees in physics) understanding of angular motion, including concepts such as angular displacement, angular velocity, and angular acceleration. Overall, their results indicated that there was little difference in the performance of students and teachers, which the researchers sought to understand. Teachers stated that earlier in their careers they would have been better at solving physics problems but their abilities had become blunted because of the prevalent "teaching to test" approach (Mashood & Vijay 2012, p. 1307). In addition, the teachers stated that this "teaching to test" approach did not actually assess students' conceptual understanding or allow teachers to focus on the necessary conceptual understanding in their teaching practice. Similarly, Mutsvangwa (2020) conducted a study at a South African university that identified student teachers' poor understanding of angular motion concepts and found that these teachers struggled with conceptual understanding of angular motion.

Based on studies of students' problem-solving involving physics concepts (but not specifically angular motion), several researchers recommend that physics teachers need to model both conceptual and procedural aspects in problem-solving in their pedagogy (Gaigher 2006; Huffman 1997; Rayner 2005; Van Heuwelen 1991).

2.2.4 Multimodal language and meaning-making

Physiotherapy education and physics education scholars have long paid attention to the role of various modes, or forms of representation, for communicating meaning in these disciplines, including computer-generated simulations (Blackford et al. 2015; Gough 2016; da Silva et al. 2021), symbols in symbolic equations (e.g. Lemke 1998b; O'Halloran 2000; Sherin 2001), and images (Fredlund et al. 2012; Fredlund et al. 2015; Van Heuwelen 1991).

This language-focused research has been conducted from a wide range of theoretical perspectives, including Vygotsky's socio-cultural theory of learning (Kohl & Finkelstein 2017) and cognitive theory (Opfermann et al. 2017). Another perspective, which I have adopted, is that of multimodal social semiotics, used extensively for the study of procedural and conceptual understanding in science (e.g., Airey & Linder 2009; Jaipal 2010; Lemke, 1998; Tang et al. 2016).

As later described (2.3), multimodal social semiotics offers a perspective of semiotic resources, as central to accessing, learning, and communicating disciplinary meaning. According to Jewitt et al. (2001), modes are "…organized, regular, socially specific means of representation" (p. 5) and are resources for meaning-making. This literature review indicates that these representational means may be named using a variety of terms such as 'semiotic resources', 'modes' and 'language modes', and in reference to specific literature in this dissertation, I have preserved the term/s used by the authors. However, all such uses are informed by a rich understanding of the notion of 'language' (Kress and van Leeuwen, 2006), to extend beyond the modes of verbal talk and written text, and include symbols and symbolic equations, images, gestures, objects, and tools. In this study, I have chosen to use 'multimodal language' or 'language modes' interchangeably to refer to this rich conception of 'language'. While the use of 'mode' and 'language' together may be interpreted as a tautology, here it represents a conscious choice to maintain a central focus on language as multimodal in nature, and to make this text more accessible to a reader unfamiliar with the terminology of social semiotics.

Airey and Linder (2009) focused extensively on the discourse of university science disciplines, including detailed attention to physics, from a multimodal social semiotic perspective. Specifically, they conceptualise a disciplinary discourse such as physics, as consisting of a multimodal suite of representations, tools, and activities. They emphasise the importance of all university students developing disciplinary literacy (Airey & Linder, 2017), which means that all members of a discipline should be able to engage proficiently with and move fluently between different disciplinary language modes. This disciplinary literacy, they argue, is important for communicating the particular ways of knowing and doing in a discipline (such as physics). Additionally, as suggested by the literature reviewed in section 2.1.3, it is important to be able to flexibly apply these ways of knowing and doing in physics to relevant contexts in disciplinary practice (such as physiotherapy practice in my study).

Van Heuwelen (1991) used a multimodal perspective to explore how first year university students understood and solved a physics problem using written words in a problem text, iconic images, symbolic drawings (such as vectors and graphs), and mathematical equations. He found that students could use the mathematical equation to solve the problem. However, they had poor conceptual understanding of the problem which can be attributed to their lack of attention to modes other than symbolic equations. He recommended that teaching should not predominantly focus on problem-solving using equations, but that time should be spent teaching students to solve problems qualitatively, focusing on conceptual understanding and using various language modes to do so. Fredlund et al. (2015) who investigated how modes were used by a lecturer in meaning-making of the physics concept of refraction, assert that use of modes must be carefully planned for the potential meaning they intended to provide.

Multimodal meaning-making has been investigated in relation to both pedagogy and student learning of different concepts in various disciplines. I will review studies on lecturer pedagogy as my own study focuses on meaning-making for the concept of angular motion in physiotherapy education, exploring what the lecturer does and why. While my review did not yield any studies focusing on the use of multimodality in the pedagogy of angular motion for physiotherapy, several studies highlighted the value of investigating a multimodal approach in pedagogy for meaning-making in other science disciplines, and its contribution to educational development practice. For example, Jaipal (2010) examined how a teacher used multimodality in a Biology lesson (for the concept of chemosynthesis), and she found that using a multimodal approach enhances meaning-making opportunities for students. Tang et al., (2016) explored how modes are used by teachers in a chemistry lesson. Some findings suggest that to develop students' disciplinary literacy, it is important to use discipline specific terms as well as link what is represented visually with a verbal explanation. Le Roux and Kloot (2020) investigated an Engineering lecturer’s multimodal language use in an illustration of problem-solving that focused on motion relative to a rotating axis. One of their key findings pointed to the lecturer's use of multimodal language to provide conceptual understanding during the problem-solving process. What these studies highlight is that having an idea of the affordance of a particular mode can influence the choice about the language modes to use and how they will be used in a specific context. According to Kress (2014, p. 72) awareness of “the affordances and constraints of the different language modes helps the communicator to decide what will be selected to do what.”

2.3 Theoretical framework

2.3.1 Social semiotics and meaning-making

The theoretical framework for my study is grounded in the theory of social semiotics, with its roots in the work of Halliday, Pierce, and Saussure. I draw specifically from the use of this perspective by Lemke (1998) and Jaipal (2010) in science disciplines as the theoretical lens to view and analyse meaning-making in pedagogy in the context of my study. Halliday (1993) explains that, from a social semiotic perspective, language is functional; that is, it is central to meaning-making in practices and activities within social contexts. Although Halliday's work in social semiotics focuses on the semiotic resources of verbal and written text, Kress and van Leeuwen (2006), Lemke (1998), Jaipal (2010) and O' Halloran (2000) extend this focus to other modes, including symbols and symbolic equations, images, objects, tools, and activities.

Halliday (1993) argued that language has three meta-functions, called *ideational, interpersonal,* and *textual* meanings. The Ideational function of language allows for the communication about, for example, experiences, relationships, and things. The interpersonal function of language relates to the social interactions involved in the communicative process. The textual function of language relates to how language is structured in a cohesive and coherent way during the communicative process.

Scholars have developed (and in some cases renamed) these three meanings for specific disciplines (see table 2.1). For example, Lemke developed an analytical toolkit consisting of three functions to assist with understanding meaning-making in science contexts. Lemke (1998) explains that in communication, modes function to provide presentational (ideational), orientational (interpersonal), and organisational (textual) meaning. According to Lemke, presentational meaning tells us about a topic, theme, processes, the participants, and the relationships between participants. Lemke (1998, p. 92) refers to this as the "state of affairs". Orientational meaning is the stance taken towards those involved in the communication process and stance in relation to what is communicated as part of the presentational meaning. Orientational meaning also tells us about the role, or position, of those in the communication process. Organisational meaning conveys how the parts and the whole relate and are connected.

Table 2.1 Meta functions of meaning

Scholar	Meta functions		
Halliday (1993) *applied to verbal and written language*	**Ideational** communication about experiences relationships or things	**Textual** how the text is organised, words in phrases, phrases in clauses	**Interpersonal** how text enacts interpersonal relationships
Lemke (1998) *applied to meaning - making in science*	**Presentational** communication about topics, themes, processes, activities	**Organisational** how the parts are organised in relation to the whole and the connecting relationships	**Orientational** stance towards what is being communicated, stance towards those involved in the communication process, how those involved in the communication are positioned in relation to the context
Jaipal (2010) *applied to the example of teacher's pedagogy for meaning-making in a Biology lesson*	**Presentational** conceptual aspects of meaning, explaining meanings, making predictions and arguments	**Organisational** pedagogical aspects of meaning, the teaching structure and sequence of topics, lessons, concepts	**Orientational** Social aspects of meaning, interpersonal relationships, roles and status of student and teacher

Jaipal (2010), whose interest like mine is in multimodality for pedagogy, further developed the three meta-functions defined by Lemke (table 2.1). Jaipal ascribes conceptual meaning to the presentational function of modes, which relates to the meaning of concepts and content. For her, conceptual meaning refers to the way the teacher explains concepts, explains relationships between different concepts, and justifies and makes scientific predictions. This aligns with the definition of conceptual understanding I use in my study (1.2). Jaipal (2010) ascribes the "social aspects of meaning" to the orientational function of modes and applies it in the same way Lemke (1998) does. Orientational aspects of meaning relate to the roles of those involved in the communicative process as well as the stance taken by the role-players in relation to content and conceptual meanings communicated in a social context. This is important for my study because it considers the roles of the lecturer and the student in relation to the presentational meaning, in the context of physics and physiotherapy. Finally, Jaipal (2010) applies the organisational function of meaning to the "pedagogical aspects" of the lesson, which can be considered at both a micro level (such as how the modes are used to organise meaning) and at a macro level (how the teacher organises the lesson and how concepts and procedures are sequenced in order to give meaning to the parts and the whole).

Kress et al. (2014, p. 15) assert that the teaching is an expression of the motivated choices from the meaning-making resources available to the teacher in a particular time and context. Exploring the meanings that can and must be made in the classroom, requires the consideration of the choices made by those communicating meaning. This includes exploring how meaning is constructed using the available modes withing a specific context. These contextualised choices are linked to the affordance of a particular mode to communicate the intended meaning within a specific context (Kress & Selander, 2012)

2.3.2 Modes and their affordances

From a social semiotic perspective, each language mode has particular meaning-making potential, referred to as the affordances of a mode (Jewitt 2016). Lemke (1998), Kress et al. (2014), and Jewitt (2016) assert that each mode has the affordance of communicating meaning about specific elements of a concept or procedure, and when taken together, they contribute to a comprehensive representation of the attributes of the concept. In this section, I focus on the language modes and their affordances relevant to my study: verbal talk, written text, symbols, images, gestures, and objects.

2.3.2.1 Verbal talk

In this study, verbal talk refers to how words, which are intended to be audibly perceived, are used individually and/or in combination to perform the three meta-functions of language

(2.2.1) to give meaning to concepts and procedures. It refers to the verbal naming and description of concepts, symbols, and procedures. Specifically, it examines how concepts are named using their scientific and common names, and how the properties of concepts are verbally described (e.g., "rotated" versus "spun"). Verbal talk also has the affordance in pedagogy of organising content (e.g., "circle, radius, and arc length") and showing links between parts of content (e.g. "similar to", "like" and "which means"). Finally, verbal talk has the affordance of positioning those involved in the process of communication (e.g. "when *we* did linear motion") or orientating those involved in the communication process towards a particular stance about what is being presented (e.g. "this is how we represent it").

2.3.2.2 Written text

I use written text to refer to the use of words individually and/or in combination in textual form (e.g., words written on a blackboard). This refers to the written scientific names for concepts, symbols, and procedures. For example, the phrase "arc length" may be written next to its symbolic representation 's'. Like verbal talk, concepts may be named in writing using their scientific or common names. A lecturer may provide written descriptions of the properties of concepts and use written words to frame a problem to be solved. The arrangement of written text on the board has the affordance in pedagogy of organising meaning by showing links between parts of content. Written text has the affordance of representing a record, in a textual format, of what students heard the lecturer say audibly.

2.3.2.3 Symbols and Symbolic equations

Symbols are commonly used in mathematics and science disciplines to represent concepts in a contracted form (e.g., the symbol '*s*' for the concept of arc length). Symbols are used together in an equation to represent a concept and its related concepts. For example, angular displacement is represented symbolically by the equation $'\theta = \frac{s}{r}'$, where 'θ' represents the concept of angular displacement, 's' represents the concept of arc length, and 'r' represents the concept of radius. O'Halloran (2000) explains that when symbols are used in a mathematical equation, the symbolic equation has the affordance of representing the relationship between variables (and concepts) in a contracted form. It allows a process of quantifying the variables (or concepts) in the equation during problem-solving and/or manipulating the relationship between variables to solve for an unknown variable.

2.3.2.4 Images

Harrison (2003) identifies three categories of images: icon, symbol, and index. An icon has a similar visual resemblance to the actual object or person it represents, for example, a stick figure drawing of a person.

An indexical image, unlike an icon, has no resemblance to a person or object but it is recognisable because we have come to know and understand the link between the index and the concept it represents (Harrison 2003). For example, arrows are used indexically to focus attention on certain aspects of importance or to imply a relationship, such as an arrow placed between a written word and a symbol indicating that the two are connected. In pedagogy, an index is often accompanied by a short written text to explain the concept it represents.

The third category of images are symbolic (Harrison, 2003), and have no visual resemblance or conceptual link to an object or person. We only know what the symbol means because of its convention in society or a particular discourse. In my study of the discipline of physics, graphs or free body diagrams are examples of symbolic images.

2.3.2.5 Gesture

According to Kress (2014), gesture is a combination of motion of the hands and body, as well as facial expression that can be used to communicate meaning. Allwood and Ahlsén (2015) provide insight into the different kinds of gestures, which, like images, can be categorised as iconic, indexical, or symbolic. Iconic gestures rely on similarities with the shape or form of an image or object (e.g. gesturing a circle or arc with your hand). Indexical gestures, such as pointing a finger, are frequently used to draw attention to an image or object. Symbolic gestures are gestures that we know and understand because of conventional ways of communicating meanings. An example is the right-hand rule[1] which is used to determine the direction of vector quantities in angular motion.

2.3.2.6 Objects

Kress et al (2014, p. 83) identify the contribution of the use of objects to meaning-making in science. Here I make the distinction between disciplinary tools, which have a specified purpose within the context (e.g., a goniometer), and 'everyday' objects, which can be

[1] For further reading, see: https://courses.lumenlearning.com/boundless-physics/chapter/vector-nature-of-rotational-kinematics/

employed for meaning-making in the science classroom (e.g. balancing a ruler on your finger to illustrate the concept of centre of gravity in relation to the base of support). The affordance of everyday objects (Kress et al. 2014) is that they position the science in the everyday and, if chosen carefully, can facilitate access to disciplinary concepts.

2.4 Conclusion

The literature reviewed in this chapter identifies the need to investigate pedagogy for the concept of angular motion in physiotherapy, and the value of doing this from a multimodal social semiotics perspective. In Chapters 3 and 4, I explain how I operationalised these concepts to answer my research questions.

Chapter 3: Methods – Part 1

3.1 Introduction

The method for this study is described and explained across two chapters. In chapter 3, I explain the research design of this focused ethnography (3.2.1). In section 3.2.2, I describe the study context and provide a brief overview of the angular motion module, as well as my position as lecturer and researcher in relation to the study context. In section 3.2.3 and 3.2.4, I orient the reader to the detailed content that is explored in this study.

3.2 Research Design

3.2.1 A focused ethnography

The key aim of a qualitative study is to describe and understand human behaviour (Babbie, 2004), applied here to explore how multimodal language was used by a physics lecturer in the teaching of the physics concept of angular motion in a Biosciences course for physiotherapy students. A "real world setting" (Lillis 2008, p. 358), such as the physics lecture, is best for observing, describing, and understanding human behaviour in the environment in which it occurs. Rich descriptions of the actions of the physics lecturer were produced and an understanding of these actions in relation to the contextual experiences and choices was sought.

Hammersley (2006, p. 11) explains that the method of ethnography aims to "understand people's perspectives from the inside while also viewing them and their behaviour more distantly." This can be achieved through drawing on multiple data sources which aim to describe and understand a phenomenon and help "…the researcher maintain an openness to what may be significant to participants" (Lillis 2008, p. 360). The approach for this study was a *focused* ethnography, which has its origins in traditional ethnography but is usually a small-scale study. It is adapted to settings where time to conduct the study is limited, such as in medical or health professions education (Rashid et al. 2019), or for minor dissertations, such as this one, where the scope of the study is limited. With focused ethnography, it is preferable that the researcher is already familiar with the research context and topic, thus requiring less time in the field. As a lecturer and clinical educator in the physiotherapy programme, I am familiar with the research context.

For this focused ethnography, the data sources were lecture observations and semi-structured interviews which included participants producing solutions to a physics problem. To locate the data collection methods used, I next provide details of the lecture module in focus.

3.2.2 Description of the study context and angular motion module

This study focused on the five-lecture module on angular motion. The lectures took place in a flat venue, with 43 students seated in rows. The lecturer was positioned behind a lectern at the front and centre of the classroom. The lectern had a document camera that projected what the lecturer wrote or drew onto two screens positioned on either side of the lectern. Between the screens was a wall-mounted white board that the lecturer used. All lectures were recorded, and students had access to the recordings via the online learning management system (LMS).

The lecturer was responsible for teaching the entire physics module. Each lecture was 40-minutes long. In the first two lectures in the angular motion module, the lecturer focused on the concepts of angular displacement, angular velocity, angular acceleration, mathematical problem-solving procedures, and the process of conversion. The last three lectures focused on problem-solving: students were given physics problems that they worked through individually, then the lecturer would demonstrate and explain a step-by-step solution. During lectures, students could ask questions at any point, and the lecturer occasionally posed questions to the class.

Students also attended a weekly tutorial, prior to which they would receive a worksheet with a range of problems similar to those solved in class. Completed worksheets were submitted prior to the tutorial, and the tutorial was used to provide students with feedback as the tutors demonstrated the solutions.

The assessments consisted of mini *ad hoc* tests, tutorial worksheets, a class test, and a final semester examination. The assessment problems were similar in complexity to the problems solved during lectures and tutorials. The lecturer was responsible for setting the tests, the worksheets for the tutorials, and the final examination.

The lecturer has a background in biomedical engineering. At the time of the study, she had lectured on the course for three and a half years, and prior to that she was an undergraduate tutor as well as a tutor for high school students.

3.2.3 My position in relation to the research context

Although I am a practising physiotherapist and teacher, over time, my knowledge on angular motion, when applying it to patient care and teaching, became tacit. As the researcher, it was important to re-acquaint myself with this knowledge and gain insight into what I needed to understand about angular motion to address the research questions. I did this through an iterative process, both early in the study and again at various points throughout. I consulted a range of resources to help my understanding of concepts and processes, watching online teaching videos, reading the course notes, and consulting faculty lecturers who had a biomechanics background. This served the primary purpose of revisiting the content. Watching the five recordings of the physics lectures on angular motion during data collection gave me an overall sense of the classroom context, the flow of the lectures, and the angular motion module. Together, these insights guided my design of the data collection tools, namely the relevant angular motion problem-solving task, the questions to ask in the "talk around text" (Lillis 2008, p. 355) about the problem-solving, and the semi-structured interview questions where I aimed to understand the lecturer's choices during her teaching in the lectures I observed.

3.3 Angular motion – concepts and processes

In this section, I present the concepts and processes related to the angular motion module to orient the reader to the content explored in this study. Angular motion falls under the topic of kinematics. In the course notes (Biomechanics for Physiotherapists: Displacement, Velocity and Acceleration 2011), it is explained that motion is defined by:

- the position of the body
- the direction the body is moving and how it is moving, i.e., whether in a straight line or not
- the speed of the motion
- whether the motion is accelerating, decelerating, or remaining constant

Within the larger kinematics module, the angular motion module is preceded by the module on linear motion, which refers to the motion of a body along a straight line (Figure 3.1). In contrast, angular motion considers the rotation of a rigid body about a fixed axis along a circular path, for example, the motion of an outstretched arm (rigid body) moving along a circular path (Figure 3.2). Linear and angular motion are vector quantities, having both magnitude and direction.

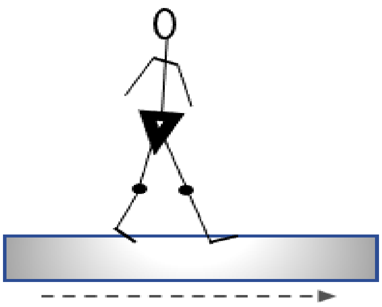


Figure 3.1 Linear motion walking in a straight line

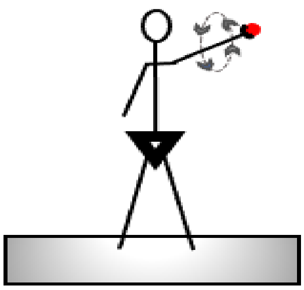


Figure 3.2 Angular motion moving the arm in a circle

An overview of the key angular motion concepts, their relations, and the related mathematical procedures that are applied to problem-solving are illustrated in the concept map (Figure 3.3). In the lectures in this study, concepts were taught in sequence (indicated by the numbering within the figure), with the arrows signifying that the meaning of subsequent concepts were dependent on the understanding of the preceding concepts. The detail related to this concept map is explained in the rest of this section, using the problem I developed for the study interviews.

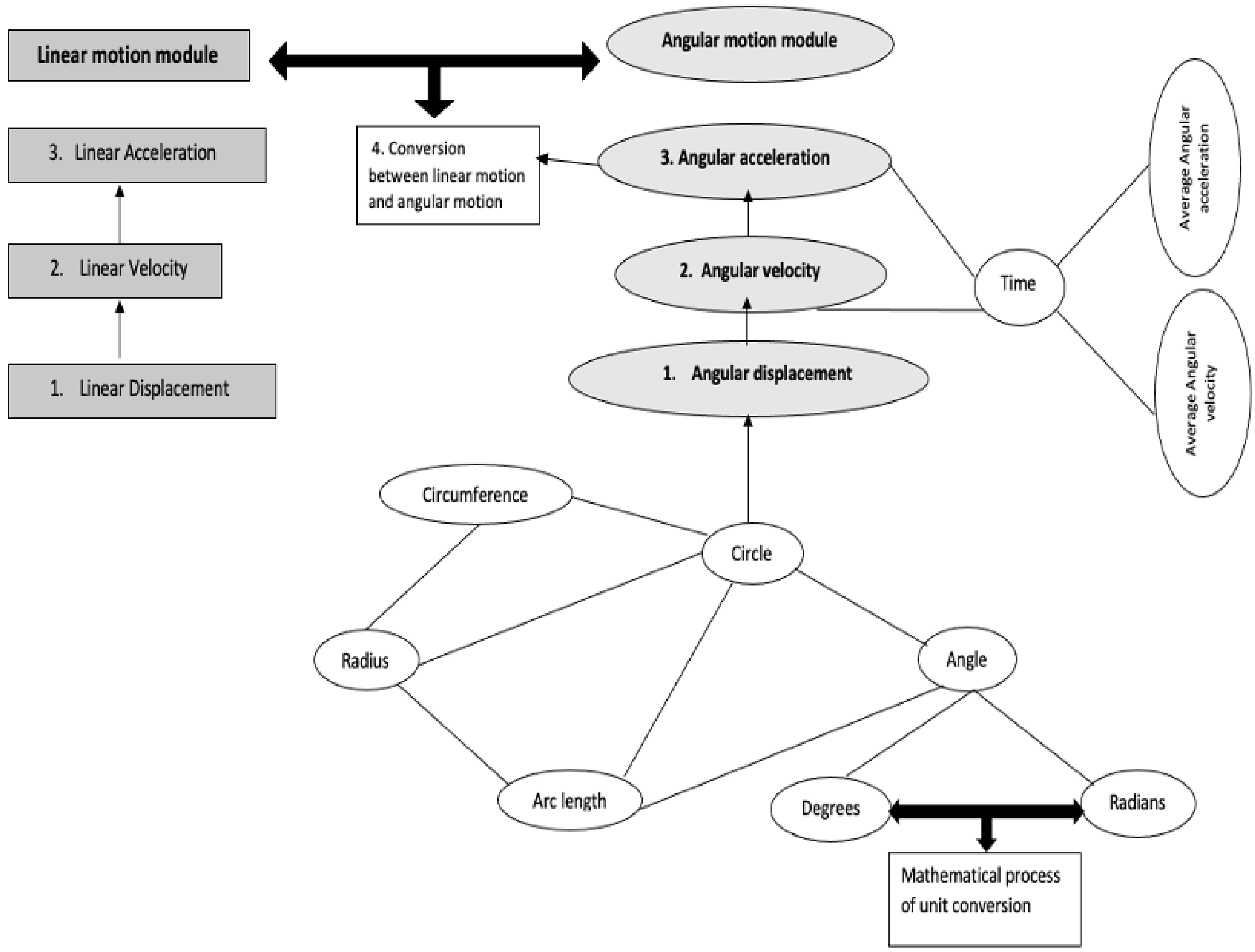
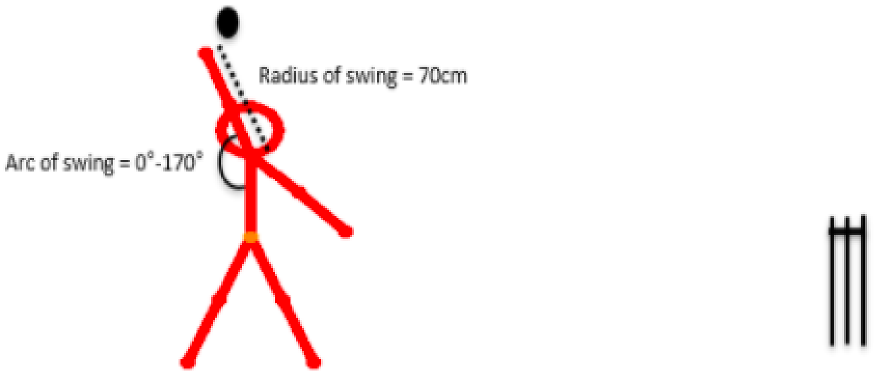


Figure 3.3 Concept map

After mapping these concepts (Figure 3.3), I designed an angular motion problem (Figure 3.4) which was similar in complexity to the problems students encountered in the course. In this dissertation, I use this problem example to explain the conceptual and procedural understanding needed to solve an angular motion problem (section 3.2.3) and hence how a student might solve the problem (Appendix A). The concepts that will be explained are angular displacement, angular velocity, angular acceleration, and conversion between motion.

Question:

A bowler is participating in a cricket fitness session. As part of his training he bowls in the cricket nets. While watching him bowl, you observe that he swings his right arm from 0° through an arc of 170° before the ball leaves his hand. The motion took 0.8 seconds. The radius of the swing was 70 cm.



1. Determine the angular acceleration of the bowler's arm during the motion.
2. Determine the final angular velocity of the bowler's arm just before the ball leaves his hand.
3. Determine the final linear velocity of the bowler's arm.

Figure 3.4 Angular motion physics problem

Angular displacement requires an understanding of the concepts of circle, radius, circumference, arc length, angle, radians, and degrees. In figure 3.4, the bowler is swinging his arm in an angular motion with the shoulder being the axis of the motion. This swinging action creates a path of movement that forms an imaginary circle. The bowler's arm, which represents the radius of the movement, forms an arc of movement as it swings (Figure 3.5). The arc length is the distance moved by the arm and is quantified in degrees in the problem text. The arm swings from 0° (start of the motion) to 170° (the point where the ball is released). This distance that the arm moves in a circular path is its angular displacement**.** Angular displacement is quantified using the equation $\theta = \frac{s}{r}$, where the Greek letter 'θ' (theta) is the symbol for angular displacement, 's' is the arc length and 'r' is the radius (Figure 3.7).

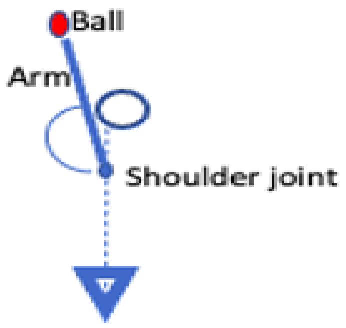


Figure 3.5 Bowler's shoulder, arm, and ball in hand

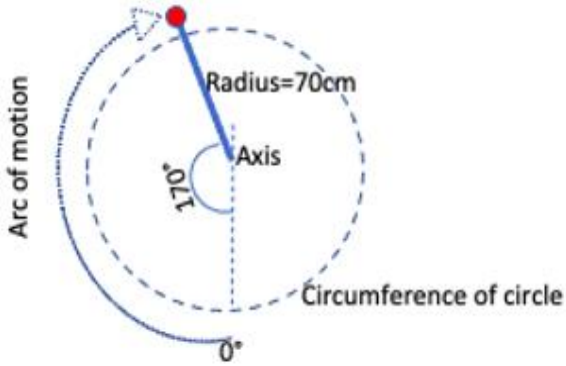


Figure 3.6 Circle formed by arc of movement

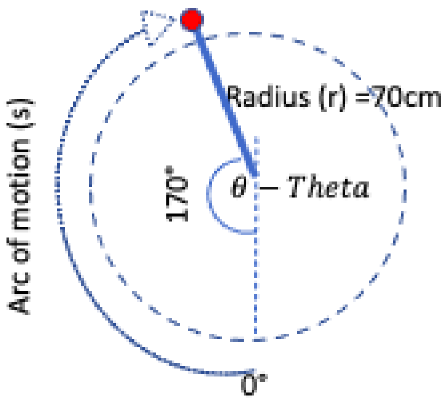


Figure 3.7 Angular displacement

If the arc length 's' has the same length as the radius 'r' of the circle (Figure 3.7), the angle subtending that arc is 1 radian (rad). In this course, angular displacement must be measured and expressed in radians. Therefore, in the bowler problem, degrees must be converted to radians by using the unit-conversion chain link method.

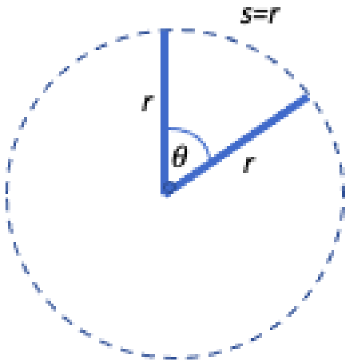


Figure 3.8 1 radian (s=r)

As illustrated in the concept map (Figure 3.3), understanding angular displacement becomes the foundation for understanding angular velocity, which refers to angular displacement over time. In relation to the example, angular velocity refers to how fast the bowler swings his arm, i.e., the rate of change of the angular displacement (Figure 3.9). In relation to Figure 3.4 question 2, the angular velocity can be quantified using the equation:

$\omega = \frac{\theta_2 - \theta_1}{t_2 - t_1}$ also expressed as $\omega = \frac{\Delta\theta}{\Delta t}$, where the Greek letter 'ω' (omega) is the symbol for angular velocity in the equation. The unit for angular velocity is radians.s^{-1} (radians per second) in the direction of the motion which is always perpendicular to the plane of rotation.

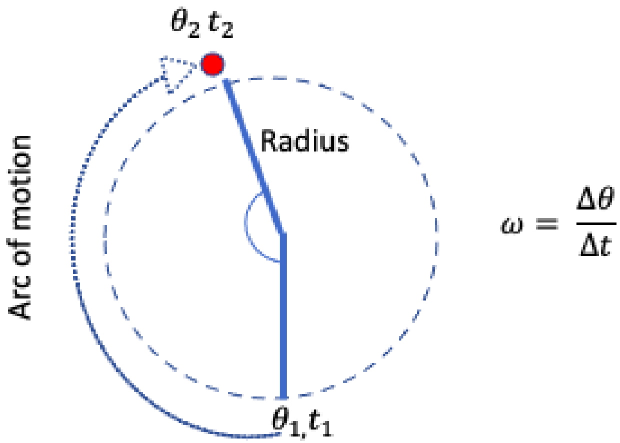


Figure 3.9 Angular velocity

When working with angular acceleration, the related concepts of angular displacement, angular velocity, and time are important to understand. Angular acceleration refers to the rate at which the angular velocity of a rotating body changes. In the case of the bowler, it refers to the rate of change of the velocity at which he swings his arm (Figure 3.4, question 1). This is quantified through the following equation:

$\alpha = \frac{\omega_2 - \omega_1}{t_2 - t_1}$, also expressed as $\alpha = \frac{\Delta\omega}{\Delta t}$

The Greek letter 'α' (alpha) represents angular acceleration in radians.s^{-2} (radians per second per second) in the direction of the motion which is always perpendicular to the plane of rotation.

If an object traveling in an angular motion were to come loose from its path, it would continue to travel in a straight line, i.e., tangentially to the angular motion at the point the object left its circular path. Conversion equations allow us to convert from one type of motion to the other, and in the case of the bowler example, it allows the calculation of the tangential velocity, if we have information about either the angular or tangential motion. Thus, the notion of conversion between angular and linear motion is another key concept, and conversion equations allow the 'converted' motion to be quantified. As an example, linear velocity, which is the tangential velocity, can be graphically depicted as shown in Figure 3.10.

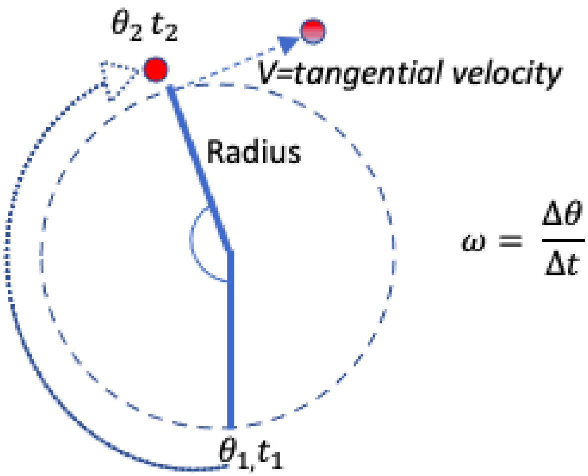


Figure 3.10 Tangential velocity

The conversion equations are listed and this relationship between the variables is represented mathematically by the *conversion equations,* where $'s'$ represents linear displacement, 'v' represents linear velocity, and $'a'$ represents linear acceleration:

$$s = \theta r$$

$$v = \omega r$$

$$a = \alpha r$$

3.4 Solving the angular motion problem

To solve the angular motion problem (Figure 3.4), three sets of equations can be used: linear equations of motion, angular equations of motion, and conversion equations (Table 3.1). In course assessments, the linear and angular equations are given in symbolic form, but students are expected to remember the conversion equations. Table 3.2 is a summary of the symbols in these equations and the concepts they represent.

Linear equations of motion		Angular equations of motion		Conversion Equations	
$v = u + at$	Linear velocity	$\omega_f = \omega_i + \alpha t$	Angular velocity	$s = \theta\, r$	Displacement
$s = ut + \frac{1}{2}at^2$	Linear displacement	$\theta = \omega_i t + \frac{1}{2}\alpha t^2$	Angular displacement	$v = \omega r$	Velocity
$v^2 = u^2 + 2as$	Linear acceleration	$\omega^2 = {\omega_i}^2 + 2\alpha\theta$	Angular acceleration	$a = \alpha r$	Acceleration

Table 3.1 Equations for solving problems

Table 3.2 Symbols and related concepts

Symbol	Symbol name	Concept
ω_f	omega *f*inal	Angular velocity (final)
ω_i	omega *i*nitial	Angular velocity (initial)
α	alpha	Angular acceleration
θ	theta	Angular displacement
t	time	Time
s	Letter "s" or displacement	Linear displacement
v	Letter "v" or final velocity	Linear velocity
a	Letter "a" or acceleration	Linear acceleration
u	Letter "u" or initial velocity	Linear velocity
r	radius	Distance from centre of circle to circumference

For the full solution to this problem (Figure 3.4) which was solved by participants during the interviews, please see Appendix A.

3.5 Conclusion

In this chapter, I provided an overview of this focused ethnography and orientated the reader to the research context. I also detailed the content explored in the study. In Chapter 4, I continue the description of my methods as I explain the collection and analysis of data, and the ethical considerations.

Chapter 4: Methods – Part 2

4.1 Introduction

In chapter 4, I describe the collection (4.1), production (4.2), and analysis (4.3) of my data set, and the ethical considerations applied in this study (4.4).

4.2 Data Collection

The two key data sources in this study were the lecture observations and lecturer interview. The observation, conducted first, was analysed to describe the lecturer's pedagogy and use of multimodal language for meaning-making. It also informed the design of the subsequent semi-structured lecturer interview. Used primarily as part of my research design process, I also conducted student interviews (Appendix B). The content of these student interviews informed the specific focus of the research reported in this dissertation, specifically, it informed my decisions about which teaching moments to present in the data analysis (4.3). The student interviews, which focused on their use of multimodal language for meaning-making and their experiences of the lecture pedagogy, are, in themselves, deserving of a detailed study. Yet, understanding student practice and experience must be informed by an understanding of the learning opportunities created by the lecturer. Thus, considering the scope of a minor Masters study, the focus of this dissertation is on describing and explaining the latter, using the analysis of the lecture observation and lecturer interview. For a description of the student data collection process refer to Appendix B.

4.2.1 Lecture observation

Originally, I intended to conduct observations by attending the live lectures, and then watching the lecture recordings that are made available through the online LMS. However, ethical approval for this study was only received a few days after the teaching concluded. Therefore, I was only able to watch the recordings of the five lectures to collect the observational data. Fortunately, the quality of the recordings met the needs for the planned study of the lecturer's use of multimodal language in her pedagogy. The audio-visual recording equipment was positioned to focus on the front of the venue and the lecturer stayed within range of the camera. The students are not identifiable in the recordings. Overall, student input in the lecture was rare. However, audible, but unidentifiable, student comments were considered in the lecture analysis, without compromising ethical principles.

Reeves et al. (2013, p. e1367) make reference to Atkinson (1994), who asserts that, with the expansion of ethnography into online spaces, researchers are no longer restricted to being in the same space as participants at the same time. In fact, Jewitt (2012, p. 6) refers to video records as a "fine grained multimodal record" that puts "talk in context" in relation to other modes and allows researchers to determine how the modes "elaborate one another".

In my initial viewing of the recorded lectures, I paid attention to the content by identifying the concepts and mathematical procedures that the lecturer focused on, and the sequence in which she did this (3.2.3 and 3.2.4). I also noted how she used the language modes, namely verbal talk, written text, images, gesture, symbols, and equations, as well as her use of objects, to provide presentational meaning. I recorded these observations in a table (Table 4.2), including the sequence followed and the modes used.

4.2.2 Lecturer interview

To understand the lecturer's choices in context, I collected data through a semi-structured interview. The three-part, interview lasted for one hour and 45 minutes and was audio-recorded (see Appendix C, for lecturer interview question schedule).

In **part one,** the lecturer solved the three questions of the angular motion problem (3.2.3, figure 3.4). While observing her problem-solving, I made field notes about the steps she followed and questions I wanted to ask.

After she solved each question, we engaged in a "talk around text" (Lillis, 2008). Specifically, I focused on key concepts, their relatedness, and key processes (3.2.3, figure 3.3) to investigate why these are important and what she felt students found difficult in relation to these. For example, I asked, "Is it necessary for students to include the direction of the motion? Why?" and "Do students understand the notion of conversion between two types of motion?".

Part two focused on my questions about the lecturer's planning for lectures, her experience of having taught the angular motion module, her evaluation of the preparedness of students for university physics, and their performance in assessments. I followed the interview schedule but also permitted the conversation to flow to allow the lecturer to share what she felt was relevant and important. I also checked my understanding of what she explained throughout the interview, by paraphrasing and summarising what she shared to make sure I did not misinterpret or misrepresent her.

Part three consisted of watching and discussing 12 video clips I chose from the lecture recordings. These related to the teaching of the concepts of angular displacement, angular velocity, tangential velocity, and problem-solving processes, and provided focus for exploring the lecturer's use of multimodal language. Prior to the interview, I emailed the lecturer the clips to watch, and asked her to reflect on the choices she made in relation to the way she taught.

At the end of the interview, I gave the lecturer an opportunity to add anything else that she thought was relevant to the discussion or to ask me any questions about the study.

4.2.3 Use of student interviews in the study

Having analysed the lecture observations and lecturer interview in full (section 4.3), the content from the student interviews informed the specific focus of the research reported on in this dissertation and which teaching excerpts to focus on and present in the analysis (see Appendix B, for student data collection processes). For completeness, I briefly describe how the data was organised and used.

While listening to the audio recordings of all eight student interviews, the responses of all eight were captured on a spreadsheet. Then I looked at all the content of each interview as a whole to identify similarities and differences in what students said about:

- their difficulties in the transition to and within the course
- their use of language modes for meaning
- their experiences of the lecturers' multimodal language use for these meanings

Organising the data in this way helped me identify the two lectures to focus on for the in-depth lecture observation analysis, where the semiotic analysis framework was applied.

4.3 Data Production – preparing the data for analysis

4.3.1 Data production – Lecture observation

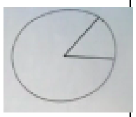
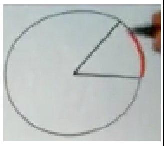
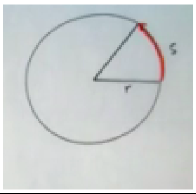
The process of data production was not linear, with production of the lecture observation being carried out in two related processes, each serving a key purpose. The first process of data production helped me to develop an understanding of the concepts and mathematical procedures that were taught, produce a concept map that detailed the concepts and mathematical procedures related to angular motion (3.2.3), and identify the sequence in which these were taught (Table 4.1). As noted in section 3.3.1, this helped me refine my data collection tools. After looking at Table 4.2, it became clear that it was during the first two lectures that the lecturer focused on key concepts and procedures related to angular displacement, angular velocity, angular acceleration, and conversion between angular and linear motion, while using a rich multimodal approach in her teaching. Based on this, I decided to limit the focus of my data production to the first two lectures.

Table 4.1 Concepts and procedures

A. Angular displacement		B. Angular velocity		C. Angular acceleration		D. Conversion between linear and angular motion	
Concept	**Procedure**	**Concept**	**Procedure**	**Concept**	**Procedure**	**Concept**	**Procedure**
1. Circle radius, arc length		1. Angular velocity (omega)		1. Angular displacement Angular velocity recap		1. Conversion linear to angular motion	
2. Motion about a circle Rotation		2. Quantifying angular velocity	3. Introduces equation for angular velocity	2. Angular Acceleration (alpha α)		2. Tangential velocity	
3. Angular displacement (theta Θ) unit radians	4. Equation for angular displacement	4. Angular velocity as displacement: time graph			3. Introduces equation for angular acceleration		3. Conversion equations
5. Unit conversion (Degrees to radians)	6. Unit conversion degree to radians		5. Mathematical process angular velocity problem solving example				4 Mathematical process conversion problem solving example, angular velocity to tangential velocity
	7. Mathematical process angular displacement problem solving example						

In the second process of data production, to prepare for the application of the analytical framework, a spreadsheet was used to organise the data based on the data produced in Table 4.1. The spreadsheet rows record the key concepts, related concepts, and mathematical procedures, and the columns record the modes. Table 4.2 is a section of the spreadsheet focused on the key concept of angular displacement and the related concept of the circle. The lecturer's verbal talk was transcribed verbatim onto the spreadsheet (Table 4.2, column B) and all the other language modes were described and screenshots included where relevant (Table 4.2 columns C-E). This aided me in the detailed analysis of the concepts, with the mathematical procedures mapped out, and in understanding how the modes were used to give meaning to these concepts, related concepts, and procedures. Once I completed this data preparation, I proceeded to apply the analytical framework to the data analysis spreadsheet (4.3.2).

Table 4.2 Content Overview Spreadsheet

	A	B	C	D	E	F
1	**Concepts/ process**	**Verbal**	**Written**	**Drawing**	**Gesture/action**	**Tools**
2	**Circle**	Let's say this is a radius		Draws a circle, draws in a line representing a radius, and draws in a second line, that is extended to a different point on the circumference of the circle 		
3	**Radius and Rotation**	So let's say I rotated about the edge of the circle			gestures rotation by making a small arc with hand	
4		Let's say I went from from here to here		highlights in red the distance between the two radii on the circumference 		
5	**Angular displacement**	So, instead of measuring the angle...let's say we have 'r' radius of our circle and arc length 's' that we moved	annotates 'r' and annotates 's' on drawing			

4.3.2 Data production – Lecturer interview

In preparation for the analysis of the lecturer interview, I listened to the audio recording of the interview and transcribed it verbatim. I followed this process twice so that I double checked the accuracy of the transcription. This allowed me to immerse myself in the data and helped me to organise the transcription into the following three focus areas:

- talk around text
- background questions about the physics course and student preparedness
- responses to questions about teaching clips

4.4 Data Analysis

4.4.1 Lecture observation analytical framework

The analytical framework was developed and refined for this study using the theory of language and meaning-making, as understood from a social semiotics perspective, outlined in Chapter 2. As noted, the three meta-functions of meaning for the analysis of the lecture observations in my study are derived from Jaipal's (2010) analytical framework (2.2, Table 2.1). The framework for my study (Table 4.3), outlines the meta functions (column A), the meaning explored (column B), and the choice of language modes used during the teaching to give the meaning (column C).

In this study, **presentational meaning** refers to the meaning given to the key **concepts, related concepts, and their mathematical procedures** in the two lectures (for example see Table 4.3, row 1).

Organisational meaning refers to how the lecturer **organises and relates** concepts, processes, and modes in her teaching; this is explored at a **macro level and at a micro level**. For macro-level organisational meaning, I analyse how the content (concepts, related concepts, and procedures) is sequenced and arranged in the teaching process, while the micro-level analysis explores how the language modes are arranged and how they relate to each other, as well as to the respective conceptual, procedural, and orientational meanings presented (e.g., Table 4.3, row 2).

Orientational meaning relates to the **stance** the lecturer takes towards what is being communicated and towards those involved in the communication process. Orientational meaning also relates to how those involved in the communication process are positioned in relation to the context**.** Orientational meaning is also related to how the lecturer **positions** the students in relation to the knowledge. Additionally, orientational meaning also involves her orientating them to how this knowledge is relevant to the context of practice as future physiotherapists (for example see Table 4.3, row 3).

Table 4.3 Analytical framework

	A. Meta-functions	B. Meaning explored	C. Language modes
1	**Presentational meaning**	i •What key concepts (e.g. angular velocity) and related concepts (e.g. radius, circumference, arc length, time) are given meaning? •What mathematical procedures are given meaning? (e.g. angular velocity mathematical process)	•verbal- how she used; descriptive language (e.g. how fast it spins, the outside of the circle), using formal scientific concept names (angular velocity, circumference) commonly used concept names (e.g. `speed`) •written- the words she wrote on the board •symbolic language- symbols and their use in equations •images- diagrams, stick figures, arrows, graphs •gesture- these included how she used her arms or body •objects
2	**Organisational meaning**	ii Macro-organisational •How is content organised and sequenced? (e.g. first circle, then, radius, then arc length, lastly angular displacement equation) Micro- organisational •What modes are used? How are the modes used individually or together and sequenced to give meaning to concepts?	
3	**Orientational meaning**	iii • What stance does lecturer take in relation to knowledge? (e.g. authority on what was important or correct, conventions in the Physics course) • How did the lecturer position herself and the students in relation to the knowledge? (students prior knowledge, positioning students as participants in the discipline, the examples she used, relevance of physics to physiotherapy profession)	

4.4.2 Lecture observation – Applying the Analytical Framework

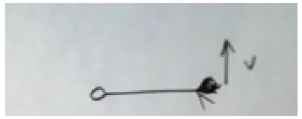
I continued to organise, produce, and analyse the data for this next level of analysis, using the analytical tools (Table 4.3) to focus in detail on the meta-functions of meaning and the multimodal language used in the lecture. I recorded my analysis in a spreadsheet. In this section, I use an extract (focusing on the concept of tangential velocity) from this table to describe my process (Table 4.4).

I used the spreadsheet rows to focus on the sequence of concepts and mathematical procedures (Table 4.4, row 1). For each row, I used the columns (E to K) to record the analysis of modes (using words or screenshots from the recording) and their related meanings, individually or together.

This layout was useful for analysing the lecturer's pedagogical approach and relating it to the meta-functions of language and the language modes used. By looking across columns for one concept, I could focus on the micro-level detail of how the lecturer used one or more modes to communicate different types of meanings. By looking across rows, I could focus on how, at a macro-level, the lecturer organised the concepts and procedures throughout the two lectures and how she used the modes for conceptual and procedural meaning.

Further detail of the application of the analytical framework and results of the analysis of specific lecture excerpts will be presented in Chapter 5.

Table 4.4 Analysis framework spreadsheet

Row	**Meta- Functions**				**Language modes**						
1	A Macro – Organisational Sequence of content	B Presentational	C Orientational	D Micro-Organisational Modes	E Verbal mode	F Specifics related to language use	G Written mode	H Symbolic mode	I Images	J Gesture	K Tools or objects
2	1	**Concept: Tangential velocity**	*Example* of throwing a ball, that is familiar to most students. Used pronouns *you,* *you've* and *your*, positions learner in the science discourse	Verbal, drawing, symbolic	So, what's gonna happen is you might get an example, where let's say (draws) you are throwing a ball, you've got a ball in your hand. But you can measure the tangential velocity (draws)	**Formal Scientific term:** 'tangential velocity' **Pronouns:** *you are, you've got, your, you can*	**'V '**	**V**	 Positioned under heading 'How do we convert between angular and linear' Iconic stick figure of arm with ball in hand, upward arrow labelled with 'V'		

4.4.3 Data analysis – Lecturer interview

My detailed content analysis of the lecturer interview, informed by the lecture observation analysis and surfaced the motivated, personal, and contextual nature of her practice.

To analyse the interview transcript, I coded the lecturer's words into units of meaning (Graneheim & Lundman 2003), described as "a constellation of words or statements that relate to the same central meaning" (p. 106). When doing the content analysis of the units of meaning, I was able to bring the analytical lens from the lecture analysis to the analysis of the lecturer's explanation of her choices in context. In the interview, she explained her choices related to the conceptual and procedural meaning she offered (presentational meaning), how she organised what she taught, and the modes she used (organisational meaning). Her responses also related to why she used certain examples, and why she took a particular stance on certain conventions and practices that were important for the students during the course or as future physiotherapists (orientational). An example of the analysis is illustrated in Table 4.5. The underlined text is the meaning units, and the boxes capture the codes which are aligned to some of the meta-functions explained here. In lines 1 and 2, she emphasises the importance of conceptual understanding for angular motion and positions students in relation to what they bring to this understanding. In line 3, she adds how she uses language modes in her pedagogy with an aim to develop their conceptual understanding.

Table 4.5 Sample of lecture data analysis

Conceptual understanding as applied to real world | Poor Mathematical/procedural understanding

Line 1: So, often, I think they have a real world understanding but they can't translate that into the maths.

Lacks conceptual understanding as applied to real world | Mathematical/procedural understanding

Line 2: Or often they don't have a real life understanding at all and the maths helps them understand physically what is going on.

Mathematical/procedural understanding

Line 3: Some of them are really good at it [maths] and some people don't really need the graphs but I can't only be teaching for half of the class, I try to teach for everybody

Teaching approach to aid understanding

4.5 Ethical Considerations

4.5.1 Ethical Approval for the study

Ethical approval was obtained from the Human Research Ethics Committee at the institution (HREC Number: 769/2018). Permission was also received from the School of Education's Research Ethics Committee at the institution (Ref number 769/2018). Permission was then received from the Executive Director of Human Resources to approach the lecturer participant, and permission for student recruitment was received from the Executive Director of Student Affairs. The study adhered to and applied the ethical principles outlined in the declaration of Helsinki (World Medical Association 2001).

4.5.2 Obtaining permissions and informed consent

An information sheet about the study was sent to the Head of the Biosciences department requesting permission to conduct the study. Once permission was granted, I contacted the course convener and the lecturer, informing them about the study. Both granted me permission to conduct the study, and the lecturer consented to be a participant by signing the information and consent document. The document explained the study information, potential risks and benefits, how confidentiality and anonymity would be ensured, how data would be shared and stored, participant rights, and researcher responsibilities. Consent from the lecturer involved her giving me permission to access the LMC to watch the recordings of the lectures and to access any Physics course notes and other resources. The lecturer was assured that the intention was not to evaluate her teaching in any way.

I arranged with the lecturer to meet the entire class. I provided verbal information about the study and the inclusion and exclusion criteria for student participants. After this, I shared the information sheets with the class. After selecting students as described in section 4.2.3, I then contacted the ten selected students with invitations to participate. Eight students agreed to participate in the study. On the scheduled day of data collection, each of the eight student participants was given an information and consent document similar to the one the lecturer received which they signed. Students were assured that their participation or non-participation would not affect their marks during the study or in the future in any way.

This study offered no rewards or monetary incentives to the lecturer and student participants. It was communicated to potential participants that the intention was to use research findings to add to the knowledge about multimodal language and its use in meaning-making for science concepts.

The study findings will be disseminated to the lecturer and wider higher education community so that teaching can be enhanced and designed to better meet student needs. For information and consent documents see Appendix D- L.

4.5.3 Confidentiality and anonymity

Steps were taken to ensure confidentiality during the research process. Firstly, I was the only person involved in the recruitment and selection of students who participated in the study. The lecturer was not aware of which students participated. Secondly, during data collection, the interviews were conducted in privacy, and interview recordings were transcribed by me. Any sharing of data with my supervisors was in the form of anonymised transcripts. For student participants, codes replaced actual names and were used in the data spreadsheets and where extracts were shared. Accordingly, participant names have not been used in this dissertation, nor will participant names be used in any publications or presentations arising from this study. Consistent with institutional data management policies, all hard copies of data were stored in a locked cabinet and electronic data was password protected. All hard copies and electronic copies of data will be destroyed after five years.

4.5.4 Recognisability

Although I considered confidentiality and anonymity, given the nature of this small-scale qualitative study and the detailed description of the research context, there is still a risk of the lecturer and students being recognisable. This is especially true for the lecturer, who was the only person who taught the Physics course.

Keeping this risk in mind throughout the research process, I firstly had to practice reflexivity (4.6.5). I reminded myself of the premise from which I approached the study, that is, that the focus of the study is to describe and explain what and how language modes are used in the meaning-making of a science concept (and not an evaluation of lecturer or student performance)**.** Secondly, my analytic tools – grounded in a social semiotic perspective of multimodal meaning-making as contextualised, motivated, and agentic (Selander & Kress 2012) – aided me in operationalising my study intentions. As described in section 4.5, my use of these tools was debated regularly with my supervisors. Thirdly, in attending to the detailed language use when writing this dissertation, I have endeavoured, in ongoing interaction with my supervisors, to represent the lecturer (and the occasional reference to student talk) in a non-evaluative manner.

4.6 Quality of the research

To argue for the quality of this study, I draw on Maxwell's conceptualisations of 'validity' and 'generalisability' in qualitative research, supplemented with Finlay's notion of reflexivity.

4.6.1 Descriptive validity

Maxwell (1992, p. 285) refers to descriptive validity as the "accuracy of the account". This means that what is reported on is an accurate representation of what took place and that the data record accurately reflects this. In my study, I aimed to accurately transcribe the verbal talk of the lecturer in the lectures and provide descriptions and, where relevant, screenshots of the other modes the lecturer used (4.2.1). I also aimed to accurately transcribe the semi-structured interview with the lecturer (4.2.2). I did this by working back and forth between the video recordings and audio recordings, ensuring that what I transcribed was an accurate reflection of what I saw and heard.

4.6.2 Interpretive validity

According to Maxwell (1992), interpretive validity refers to the relationship between the interpretation of an account and its meaning in relation to the perspective of the participants involved. Aiming for interpretive validity, during the interviews I clarified what the participant shared in response to questions I asked. I would rephrase what I heard and understood about what had been shared to ensure that I had an accurate interpretation (4.2.1).

4.6.3 Theoretical validity

Maxwell (1992, p. 291) explains that theoretical validity refers to how an account is related to a particular theory. In my study, I have worked between my multimodal social semiotic theoretical framework and the empirical study data, and have thus come to settle on an analytic framework (4.3.1 and 4.3.2). The use of the analytic framework and the way I applied it to the empirical data was debated regularly with supervisors. The findings were presented and deliberately written to show how I threaded through the theoretical concepts supported with the evidence from the transcripts.

4.6.4 Generalisability

According to Maxwell (1992, p. 293) generalisability refers to the extent to which an account of a particular situation and place (and with certain persons) can be applied to another situation that was not studied. Generalisability is based on how what is presented of the account and its processes may be useful in different situations. In this study, detailed descriptions were provided of the theoretical framework, the study context, the participants, and the study design which includes the processes of data collection and analysis. Through this, I aim to enable those engaging with the dissertation to consider the applicability of my findings to their own context.

4.6.5 Reflexivity

Reflexivity in the research process is an awareness of your positionality as a researcher in relation to the research context and process. Finlay (2002), who defines reflexivity as "thoughtful, conscious self-awareness" (p. 532), suggests that researchers need to consider how intersubjectivity influences data collection and analysis of data.

Regularly reflecting on and identifying the potential influence of my own subjectivity at different stages in the research process helped me to remain true to the aim of the study, which is to explore and understand how language modes are used in the teaching and learning of the concept of angular motion. Reflexive practice at different stages was important, especially as I made a commitment at the beginning of the study and to the lecturer that the aim of this study was not to evaluate but rather to describe and explain (4.4.2). The lecturer participant is a colleague, and so I made every attempt to make her feel at ease and to allow me to observe and explore her teaching. Furthermore, I regularly made notes of my thoughts and consulted with a peer or my supervisors when I was unsure of my assumptions or when I encountered tensions in relation to what I observed during the data collection process and while applying the analytical framework and interpreting the findings.

4.7 Conclusion

In Chapter 4, I presented my methodological choices and described how these were applied to different aspects of the study. I also provided an overview of the concept of angular motion

(Chapter 3) so that my choices can be understood in relation to the focus of the study. Lastly, I presented the ethical considerations and how those were applied as well as steps taken to ensure that the findings can be considered trustworthy.

In Chapter 5, I present the findings produced during the research process, along with evidence that shows how the analytical tools have been systematically applied.

Chapter 5:Results of Analysis

5.1 Introduction

In this chapter, I present the results of the research process described in Chapters 3 and 4. I first explain how I selected teaching moments, or excerpts, from the lecture observation analysis to present in this chapter. Next, I present the analysis of the teaching excerpts to describe what and how the lecturer gave presentational, organisational, and orientational meaning to concepts and processes using language modes, and to explain the lecturer's pedagogical choices.

5.2 Excerpt Selection

The five selected teaching excerpts illustrate how, at a macro-organisational level, the lecturer developed presentational meaning for the key concepts and mathematical procedures in the angular motion module (3.2.2 and 3.2.3), and a range of orientational meanings. At a micro-organisational level, the excerpts effectively illustrate her choices related to the language modes, and how she used the affordances of different modes individually or together to represent and link key properties of concepts and mathematical procedures as she developed meaning (See Figure 5.1 for an illustration of the macro-level organisation and the collection of modes used in the teaching excerpts).

- **Excerpt 1: The concept of angular displacement**
  Angular displacement is a foundational concept of angular motion, upon which the other concepts are developed. The lecturer uses verbal talk, written text, gestures, symbols, and indexical arrows to give meaning. In particular, this excerpt showcases how these modes, used individually and together, give meaning to the concepts related to the circle, and the relationship between the concepts in an angular displacement equation. Students indicated how the use of drawings aided their understanding.

- **Excerpt 2: The unit of measurement and process of deriving the unit of angular displacement**

This teaching moment followed directly from that in Excerpt 1, and highlights how the lecturer predominantly used the verbal talk and symbols in an equation to give meaning to the unit of measurement, the radian. She also shows that the radian is a ratio. She uses arrows symbolically to represent a mathematical procedure as well as indexically to link representations of concepts. Significant here is that, in the interview, she explained why it is important for student physiotherapists to understand the concept of radian as a ratio.

- **Excerpt 3: The concept of angular velocity**

  Prior to teaching students about the concept of angular velocity, the lecturer showed the process of unit conversion for converting degrees to radians when measuring angular displacement using the mathematical chain link method. Then in excerpt 3, the lecturer moves on to the concept of angular velocity. Here, her choices of verbal talk are noted as important for creating organisational and orientational meaning. Her use of specific words signals to students that their prior knowledge is relevant in developing their understanding of the concept of angular velocity. In the interview, she explained why she organised the use of prior knowledge to develop new knowledge.

- **Excerpt 4: Concept of conversion between angular and linear motion**

  After briefly explaining angular acceleration, the lecturer proceeds to use verbal talk, drawings, gestures, and symbols to explain the concept of conversion. She uses the example of a ball being thrown and uses an iconic drawing to develop the students' conceptual understanding. This excerpt demonstrates how the lecturer used the images to distinguish between angular and linear motion as she developed the meaning of the concept of conversion between the two types of motion.

- **Excerpt 5: The concept of a tangent and problem-solving example related to tangential velocity**

  Before giving students a problem on conversion between angular and linear motion, the lecturer introduced the conversion equations that are used to convert and determine a value for the relevant motion variable. Then in excerpt 5, she focused on the process of conversion, which shows how she uses the modes to organise the conceptual meaning related to the procedural meaning in the problem-solving example. The lecturer first unpacked the concepts in the problem example using a combination of modes, including an object. She uses an object in motion to develop understanding of the radius in the problem example. Then, using the conversion equation for velocity, she progressed to solve the problem.

The five excerpts are presented in the form of multimodal transcripts, and I describe the modes as the lecturer used them. The modes used are named and indicated in brackets (in **bold typeface**) followed by a description of the mode. Generally, each excerpt is introduced by highlighting the macro-organisational meaning of the teaching and by describing the sequence of the teaching of the concepts and processes. Following each excerpt transcript, the analysis focuses on how the lecturer organised the use of the modes at a micro-organisational level to provide presentational meaning. In addition, I comment on the nuanced use of the modes specific to each particular excerpt. Orientational meaning is presented where relevant to the excerpt. Additionally, I present data from the lecturer interview where she explained her choices and practice. Where relevant, I present data from student interviews reflecting on their learning related to the excerpts.

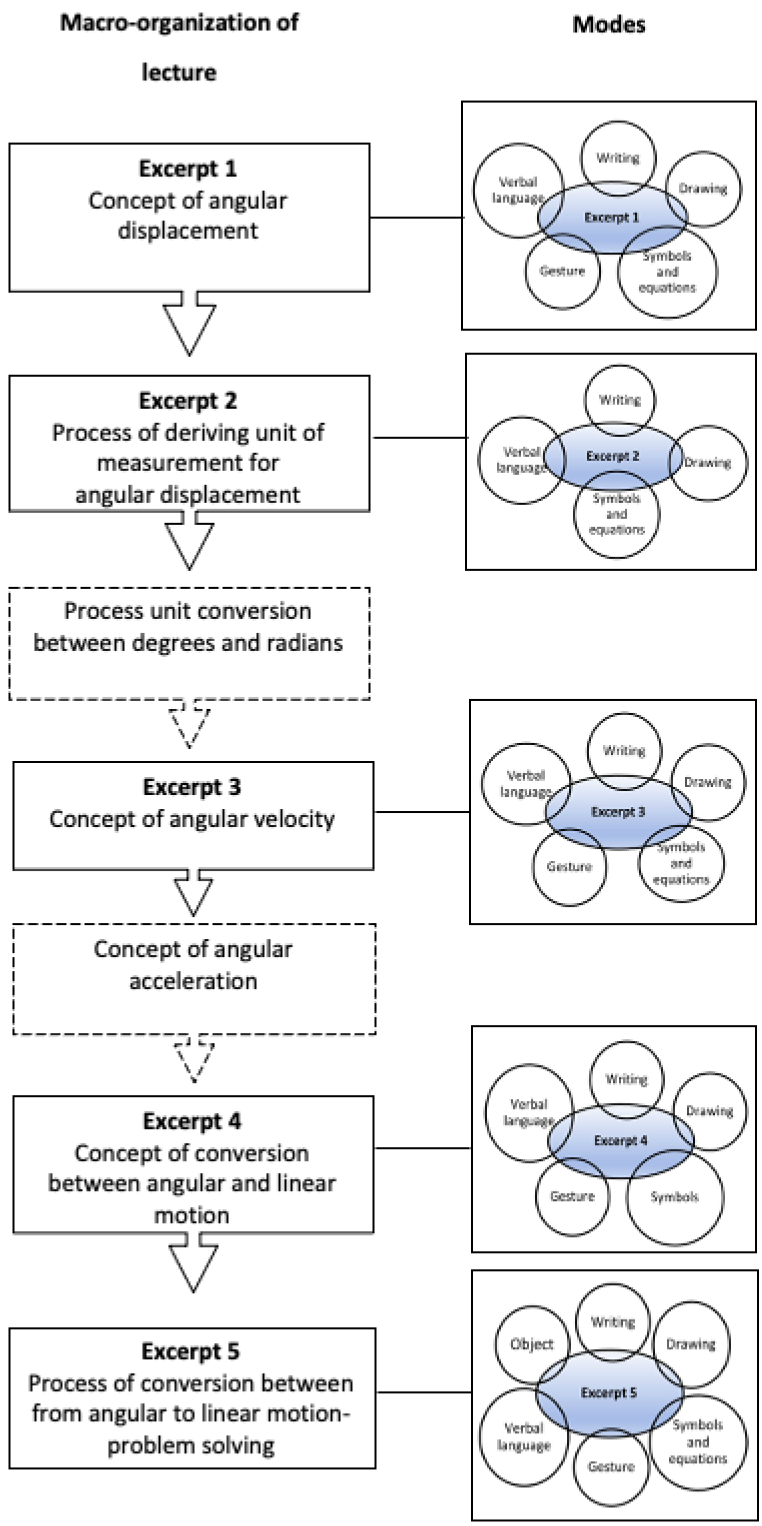


Figure 5.1 Macro-level organisation of lecture – locating excerpts and modes used

5.3 Excerpt 1: The concept angular displacement

The lecturer provides meaning to the concept of angular displacement. Macro-level organisational meaning is developed by first giving meaning to circle concepts, namely radius and arc length, and then showing the mathematical relationship between these concepts in the equation for angular displacement.

Excerpt 1

1a Let's say we have a circle (***draws*** *a circle and places a dot in the centre of the circle*, Figure 5.2) and we wanted to say this (***draws*** *in a line from the centre to the circumference representing a radius*) is the radius.

1b So, let's say I (***draws*** *in a second line, that is extended to a different point on the circumference of the circle*) rotated about the edge of the circle (***gestures*** *a small arc with her hand*). Let's say I went from here to here (***highlights in red*** *the distance between the two radii, on the circumference).* So, let's say I wanted to know the angle that I moved. It's kinda hard to always be measuring angles. So, they were like, 'surely there is something better?'

1c So, instead of measuring the angle, let's say we have *'r'* radius of our circle (***writes*** *symbol 'r'*) and arc length '*s' (**writes** symbol 's' alongside the **red arc** on the circumference)* that we moved.

1d Let's develop a relationship between these two. What if we just said '*s*' over '*r*' gives us an *angle (**writes** out symbolic equation* $\frac{s}{r} = \theta$*)*

1e So, it's more of a ratio, but it represents the angle that we're travelling *(**writes** symbol 'θ' in the angle formed by the radii of the circle, **writes** arc length and radius next to symbol 's' and 'r' in the equation and connects the words and symbol with an arrow)*

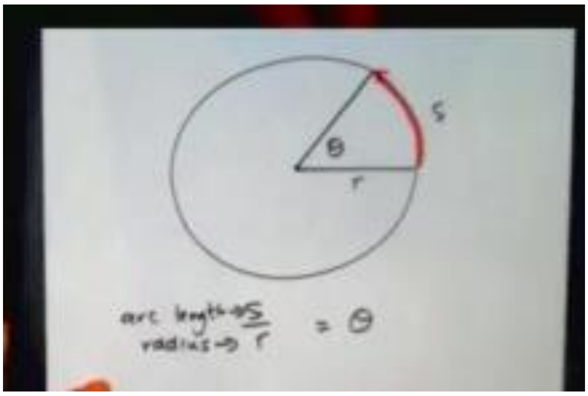


Figure 5.2 Circle and its concepts

The lecturer begins by saying “let’s say we have a circle” (1a). This, importantly, gives organisational meaning, as it signals to students to call on prior knowledge that they have regarding circles in the context of a physics classroom. Next, she provides presentational meaning by drawing the circle and then a radius, which she verbally names as such using the formal scientific concept name (1a; Figure 5.2). She then draws a second radius in the circle and gives presentational meaning to the concept of angular motion by verbally describing it as “rotating about the edge of the circle”. She also performs an iconic gesture, by motioning an arc of rotation with her hand (1b). She then uses a red pen to highlight the circumference between the radii, in doing so introducing the concept of an arc length.

Then, she verbally orientates the students to the relationship between the radii, the arc length, and quantifying the angle subtended, saying, “let’s say I wanted to know the angle I moved”. She further orientates the students towards the task of determining the angle by taking a stance towards this process saying, “It’s kinda hard to always be measuring angles. So, they were like, ‘surely there is something better?’. So, instead of measuring the angle, let’s say…” (1b). This stance communicates that what she is about to show the students is both a simpler way and a convention for solving this problem. Next, she supplements the presentational meaning provided to the circle concepts by verbally naming them, using their formal scientific concept names ‘radius’ and ‘arc length’, and annotating them with the symbols ‘r’ and ‘s’ respectively (1c).

The lecturer then makes an explicit shift to providing presentational meaning to the ‘relationship’ between these two concepts (1d). She verbally expresses the relationship as “s over r gives us an angle", importantly naming the symbols. She uses the symbols to represent the relationship in the written equation to determine what she names verbally as the 'angle'. The equation provides presentational and organisational meaning by representing the relationship between these two concepts as a 'ratio' (1d). Significantly, she then links to her drawing and annotates the angle between the two radii with the symbol 'θ' (1e). Also, in the equation, she writes out the full concept names of the symbols '*s*' and '*r*' next to each, using arrows indexically to link the meanings.

Thus, at the micro-organisational level, we see how the lecturer uses the affordances of symbolic drawing, colours, and gesture to give presentational meaning to the concepts of radius and arc length. Using the affordance of an equation, she then organises the relationship between the circle concepts and gives presentational meaning to the equation for angular displacement. During the interview, she stressed the value of gestures and drawings for the necessary visualisation for conceptual understanding: "…I swing, I walk, and I gesture, I draw and sometimes I throw objects…to get them to be able to visualise."

This analysis shows how, from the start of the teaching Excerpt 1 on angular motion, the lecturer also names these concepts verbally and/or in writing, using symbols and formal scientific concept names. In the interview, she said she chose to familiarise them with the symbols from the start as they would be using them in the equations during problem-solving. Additionally, she explained that she took time to familiarise them with "terminology" related to concept and symbol names, especially since there were so many new concepts and symbols they would come across as the course progressed. In the interview quote below, she uses the example of the term 'omega' to explain the importance of students being familiar with the concept names, symbols, and symbol names. She stated:

> So, I don't also want to shy away and then only use examples that are really easy and only use terminology that everybody will understand. I want to do the correct terminology but then we talk about… So, I don't want them to call it [the symbol for omega] a 'w', I want them to get used to omega, because we have a 'w' later and those aren't the same.

Furthermore, evident in Excerpt 1 (and elsewhere in the lectures) is that while using formal scientific concept names, the lecturer also explains the concepts descriptively. For example, she uses descriptive language like “edge of the circle” for the concept of circumference. In the interview, she identified the importance of verbal and written concept names and descriptions of these concepts (what she calls “the English”) for students' conceptual understanding and when solving problems in assessments. She also explained that she encouraged the tutors to make sure that students understood the terms and concepts related to problems they were expected to solve in tutorials.

Taken together, this use of multimodal language to represent the circle concepts culminated in her representing the concept of angular displacement symbolically in an equation which could be used in the problem-solving to come (Figure 5.1; see Excerpt 5). A student participant mentioned the value of this pedagogy for the necessary conceptual understanding of the equation, saying:

> The way she describes it and draws it as well. It was really nice to have a visual aid, as well as her talking about it. And then, also when she started writing down the formula she said what ‘s’ was and she said what ‘r’ was. So, you weren’t clueless about what that meant.

5.4 Excerpt 2: The concept of measurement and process of deriving the unit of angular displacement

Next, the lecturer gives meaning to the concept ‘radian’, as the unit of measurement for angular displacement. The unit, radian, is new to students who, until this point, have used the unit ‘degrees.’ For macro-organisational meaning, she starts her explanation using the symbolic equation for angular displacement (introduced in excerpt 1), and then substitutes each symbol in the equation using its unit of measurement. Then, through a mathematical procedure of cancelling, she shows that angular displacement is ‘unitless’ and names the assigned unit ‘radian’.

Excerpt 2

2a So, arc length is a distance. So, if we have s over r *(**rewrites** $\frac{s}{r}$ underneath the equation referred to in Excerpt 1a, Figure 5.3),* what are the units for s? Metres. What is the unit for radius? Metres *(substitutes the symbols $\frac{s}{r}$ with $\frac{m}{m}$ in **writing**)*

2b What do we get if we have metres over metres*?... 1* ***(draws** an arrow through the fraction, pointing to where she **writes** in the number one)*

2c So, this is basically a ratio, right. That's how ratios work. We say this distance over that distance. This velocity over that velocity. We use something that has the same unit**.** So, we can say this is a ratio *(**writes** the word 'ratio' and **draws** an arrow pointing to the equation)*

2d … This doesn't technically have a unit, but we are going to assign a unit and that unit is called a radian *(**writes** 'radian' underneath the equation and **draws** an arrow to link the equation with the unit name, Figure 5.4)*

2e *…* How do we represent the unit? We normally represent it as rad *(**writes** out the abbreviation 'rad' in brackets underneath the word radian)*

2f So, we can say instead of, 'I've rotated so many degrees', 'I've rotated so many radians.' So, it's just a different unit

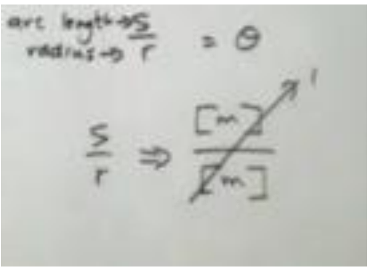


Figure 5.3 Angular displacement equation and units

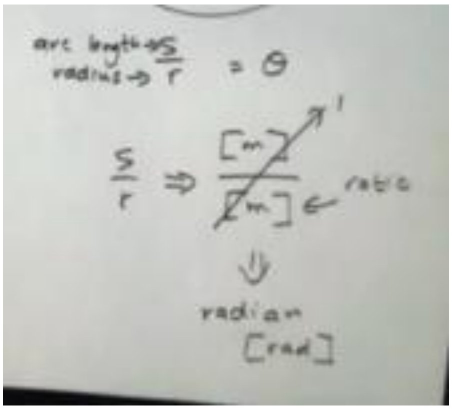


Figure 5.4 Mathematical process of cancelling

The lecturer starts by reminding students that the concepts, named verbally using the formal scientific and then symbol name as 'arc length' or 's' and 'radius' or 'r,' are distance quantities (2a). After substituting the 's' and 'r' with the unit 'm' for metres (2a), she asks a rhetorical question (2b) about the mathematical relationship when the units of the numerator and denominator are the same. She provides presentational meaning in her answer by assuming that the value of each coefficient is 1 and showing the mathematical procedure of cancelling. She draws a symbolic arrow through the fraction, showing that the units cancel each other out and therefore the fraction equals one (2b, Figure 5.3). The symbolic arrow, a representation of the process of cancelling, provides presentational and organisational meaning as it links what she explained about the process in words to its mathematical representation in the equation. She provides further presentational meaning to this mathematical relationship between the same units of measurement by equating her first explanation with examples using verbal concept names that are the same: "distance over...distance" or "velocity over...velocity" (2c). Then, having used the affordances of the spatial organisation of variables in the equation to mathematically demonstrate the conceptual relationship between these variables, she verbally describes the relationship using the formal scientific concept name, 'ratio', explaining that angular displacement is thus technically a 'unitless' quantity. She gives presentational meaning to the unit named 'radian' as the unit used for this particular ratio (2d, Figure 5.4). She writes the unit name and its abbreviated form as 'rad', linking the two representations with an indexical arrow (2e).

She also provides orientational meaning in the excerpt by positioning students as participants in the physics discipline that has particular conventions and practices (2d). She explains that the unit named 'radian' was "assigned" and shares the stance that it is how "we normally represent it" (2e). Thus, she indicates to students that as participants in the discipline they will be expected to use the unit 'radian' during problem-solving and assessments in the course. She states that the radian is "just a different unit" for measuring rotation, when previously they would have used degrees (2f). She organises this meaning by repeating the same sentence, "I've rotated so many degrees", and replaces the word 'degrees' with the word 'radians' (2f), representing the relationship between degrees and radians and drawing on the students' prior knowledge of a unit of measurement they are familiar with.

Thus far, my analysis of excerpt 2 shows how the lecturer provides presentational meaning to the unit of measurement by using a mathematical procedure. As she explains this verbally, she simultaneously writes the symbols in an equation. This organises the relationship between the denominator and numerator. The arrows have the affordance of representing a process of cancelling. An arrow also connects each formal scientific concept name with its respective symbol or concept name, which is written in close proximity to the equation.

The lecturer's interview discussion of Excerpt 2 points to the value she places on students' understanding of the unit 'radian' and the practical value of the 'ratio' concept for measuring angular displacement. She said:

> But it [radian] is very powerful because it is just a ratio. So, instead of having to have something that moves angularly [referring to a joint range measuring tool, a goniometer], I can take a piece of string from here to here [drawing a circle and pointing to a portion of the circumference as the arc length, as she explains] and put it along that arc and then I can work out what angle I moved. Just by using those two values.

In the interview, she explained this to me using a diagram, but clarified that she did not offer this explanation in class. In the student interviews, a student remarked that he felt that students were just expected to understand that "this s/r" was a ratio and felt some "groundwork" was needed to help him understand.

In the interview, the lecturer additionally positions students as future physiotherapists whose tasks entail measuring the angular motion of joints. Indeed, referring to the lecturer's practice more generally, another student participant, who did not do Physical Sciences at high school, remarked how the lecturer's explanation of the relevance of what they learned was beneficial to her:

> She tied in what we were learning in Biosciences, to our actual degree and what we going to become one day. And at the beginning I was clueless, why do we have to do physics when we're studying the human body?

These comments suggest that using the affordances of the verbal talk, written text, and images provides presentational and orientational meanings by motivating students to engage with the concept while understanding the relevance of what they learn for their future practice.

Following this explanation of the unit radians (Excerpt 2), the lecturer gives presentational meaning to the process of unit conversion from degrees to radians. She uses the angular displacement equation and the mathematical chain-link method for unit conversion. She also gave students an opportunity to practice the process of unit conversion in a problem example. I continue with the detailed analysis of excerpt 3, the concept of angular velocity, which follows directly after she teaches them how to convert from degrees to radians.

5.5 Excerpt 3: The concept of angular velocity

At the macro-organisational level, the concept of angular velocity is verbally introduced as the focus, then the lecturer introduces the symbol for the concept of angular velocity. Next, she shows them the symbolic equation for angular velocity, and then uses the graph showing angular displacement over time to expand on the concept of angular velocity.

Excerpt 3

3a So, then we're going to do angular velocity. So, again this is similar to how we were doing linear velocity.

3b So, first of all, (***writes*** *angular velocity as a heading)* the symbol is (*directly underneath the heading she* ***draws*** *the symbol ω,* ***writes*** *out the word omega and* ***draws*** *in an arrow between the word and symbol, Figure 4.4*), looks like a little weird ‘w.’ And this is an omega. This symbol is called an omega.

3c And similar with linear velocity we can say that our average angular velocity is *(**writes** $\overline{\omega} = \frac{\theta_2 - \theta_1}{t_2 - t_1}$*) theta 2 minus theta 1 over t2 minus t1, right?

3d So, again. I can draw all those graphs for you again. We can say *(**draws** the angular displacement-time graph, Figure 4.5)*. We can use this to find out the omega

3e So, do you see how that is similar to the velocity or displacement graph when we were working on average velocity? (rhetorical question) Yes? No? You still in shock?

3f So, basically, it's the same, we represent everything in the same way. Instead of it being an 's', it is now theta. Instead of it being a 'v', it is now Omega. Which is kinda like putting two Vs together.

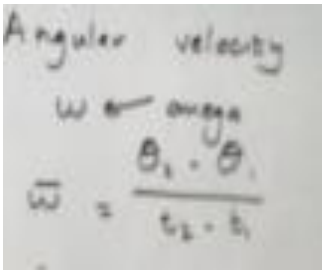


Figure 5.5 Angular velocity

The lecturer provides presentational meaning by verbally introducing the concept by its scientific concept name "angular velocity", and next provides important organisational meaning by verbally linking angular velocity to linear velocity, which was previously taught (3a). Here she also provides orientational meaning by using pronouns such as 'we' to position the student as participants in the classroom and drawing their attention to the prior knowledge that will underpin their conceptual understanding of angular velocity. In lines 3a, 3c, 3d, 3e, and 3f, she verbally includes words such as "similar to", "similar with", "same" and "again" to draw their attention to similarities between angular and linear velocity.

After introducing the new concept verbally (3a), which she then writes as the heading (3b), she introduces its symbol first in writing and then by naming it verbally using its formal scientific name, 'omega'. She spatially organises the symbol and the word 'omega' underneath the heading (3b, Figure 5.5). She provides presentational meaning here as she shows students these different ways (symbols and concept names) of representing the concept. Organisational meaning is also developed as she links these representations with an indexical arrow. Next, she uses the symbols in the representation of the equation for the concept she names verbally as “average angular velocity” (3c). Although this is the first time that she uses the word “average” in this module, she does not explain the concept of average angular velocity in detail. By using the words “similar with linear velocity” she indicates to students that their prior learning on average linear velocity is important for developing their procedural and conceptual understanding of average angular velocity. Presentationally, she represents “average” angular velocity in the equation with an overbar on the symbol omega, and this is also signalled by the differences represented symbolically on the numerator and denominator (figure 5.5).

Next, the lecturer indicates that the two concepts can be represented in a “similar way”, making a symbolic drawing of a graph showing angular displacement over time (figure 5.6). Reminding them that she previously represented average velocity as a graph (3d) when she taught linear velocity, she provides both presentational and organisational meaning through the organisational similarities in the two graphs (3e). She verbally explains the similarities in the way the graph is represented (3f) telling them that ‘S’, the symbol representing the concept of linear displacement, is the same as ‘theta,’ the symbol that represents the concept of angular displacement. She ends off by saying (3f) that instead of ‘v’, the symbol that represents the concept of linear velocity they are now dealing with is ‘omega’, which is the symbol that represents the concept of angular velocity.

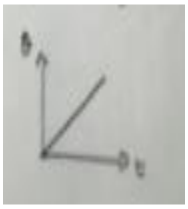


Figure 5.6 Angular velocity graph (angular displacement over time)

This analysis shows how the lecturer uses the affordance of verbal talk, symbols and symbolic equations in a specific way to organise and link learning about the concept of angular velocity to the students’ prior knowledge on linear velocity.

In the interview, the lecturer explained her choice to foreground prior knowledge by saying, "I was just trying to tie it back to the concepts that they are already familiar with…" She explained this in relation to the two types of motion:

> …I'm just trying to be like 'don't be scared of it, it is not totally new'. We're talking about all the same stuff, now it is just rotating instead of going straight, but our graphs kinda look the same. Although this all seems new, it's not new.

After explaining the process of solving for angular velocity, the students do a problem-solving example on finding the average velocity of the second hand on an analogue clock. The lecturer gives them an opportunity to solve the problem and then demonstrates the problem-solving, after which the lecture ends. The students come back two days later, when she starts off by revising the equations for angular displacement and angular velocity (Chapter 3, sections 3.2.2 & 3.2.3). She very briefly explains how angular acceleration is represented as a symbolic equation, $\alpha = \frac{\Delta\omega}{\Delta t}$, where the angular acceleration (symbolically represented as 'α', named alpha) is the change in velocity over the change in time.

5.6 Excerpt 4: Concept of conversion between angular and linear motion

The lecturer next gives meaning to the concept of conversion between linear and angular motion. At the macro-organisational level, she first explains 'why' the concept of conversion between motion is important and relevant by providing both presentational and orientational meaning.

Excerpt 4

4a So, how do we convert? (***writes*** *'how do we convert between angular and linear' on the board).* Ok, so, when we talk about converting you might just be thinking, but I just told you those two are not the same, why would we want to convert at all?

4b So, what's gonna happen is you might get an example, where let's say you are throwing a ball, you've got a ball in your hand (***draws*** *a stick figure image of an arm with an empty circle at one end representing the shoulder and the other end a hand with a ball, Figure 5.7a*)**.** But you can measure the tangential velocity (***draws*** *in an upward arrow adjacent to the hand and annotates the arrow with the symbol 'v', Figure 5.7b)*

4c So, you gonna be moving in that direction (***draws*** *in a curved arrow to represent the direction of movement of the arm, Figure 5.7c*). You gonna be rotating (***gestures*** *swinging arm in rotatory motion*). But then you can maybe measure the speed of the ball in your hand.

4d So, you will be given linear values, but that doesn't mean the ball moves in a linear motion. Does that make sense?

4e So, I'm saying (***writes*** *in symbol ω directly above the curved arrow, Fig 5.7d*) you rotate like that, but you can measure the tangential velocity or the tangential acceleration.

4f So, let's say in a case, I throw the ball (***gestures*** *throwing a ball).* So, you guys know there are those fancy things that measure how fast a ball is thrown? You get it in cricket, tennis, baseball. So, you may be able to use a device like that where you actually measure the velocity of the ball as it leaves your hand. Right, and we can convert that back into the motion of how fast they were swinging the arm (***gestures*** *swinging arm*).

The lecturer introduces the process of conversion by verbally asking a rhetorical question, "how do we convert?" (4a). She develops the presentational meaning of the process of conversion by writing down the heading ''How do we convert between angular and linear?" (4a). Thus, she indicates that the process of conversion is between two types of motion, "angular and linear". However, before explaining the process of conversion, she first focuses on the conceptual reason for conversion and verbally asks "why would we want to convert at all?" (4a).

She anchors her verbal talk using the notion of a ball in hand that is being thrown while the arm moves in rotatory motion about the shoulder (4b). This provides orientational meaning by positioning students in the classroom with an example that they might be familiar with or exposed to as future physiotherapists. Then, by drawing an iconic stick figure of an arm with a shoulder joint and a hand holding a ball, she starts to develop presentational meaning (Figure 5.7a). Macro-organisational meaning is sequentially developed as she adds to the drawing, linking to and building on what she explains about the concept of conversion between two types of motion, verbally and through gesture.

Using this example, she continues by giving presentational meaning to the two types of motion that the process of conversion will be applied to. She organises the relationship of the two types of motion as related to the concept of conversion. She explains, first, that the tangential velocity of the ball in hand can be measured while the ball is being thrown (4b). She represents the meaning of 'tangential' velocity by adding a straight upward arrow at the end of the hand holding the ball and labels the arrow with the symbol 'v' representing linear velocity (Figure 5.7b). This symbolic arrow and the symbol 'v' together communicate that tangential velocity is linear velocity. Next, she introduces the second kind of motion, namely angular velocity, by drawing a curved arrow (Figure 5.7c) representing the motion of the arm. She verbally explains that the arm is "rotating" (4b) and labels the curved arrow with the symbol $'\omega'$ representing angular velocity (4e, figure 5.7d). Then she performs an iconic gesture, swinging her arm in a rotatory motion, thus representing what she explained in words about the motion of the arm. She continues and provides presentational meaning to the concept of conversion between angular and linear motion verbally, by saying, "but then you can maybe measure the speed of the ball in your hand" (4c). Here she uses the commonly used term "speed" when referring to tangential velocity.

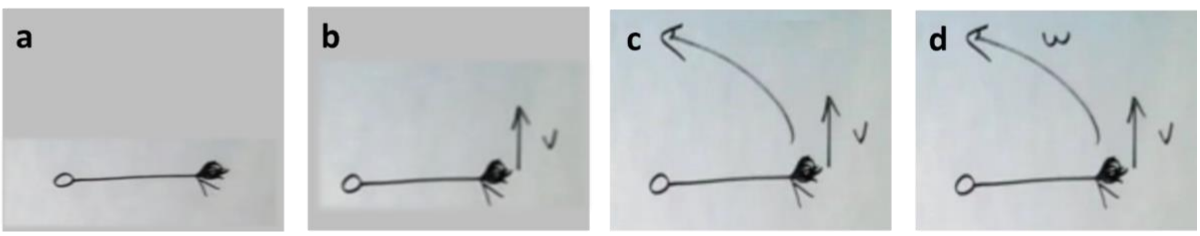


Figure 5.7 Different stages (a, b, c, d) showing ball in hand being thrown while arm moves in rotatory motion about the shoulder

To consolidate what she explained about the concept of conversion through the affordances of verbal talk, images in the form of a drawing, and the written text, she gives another real-life example of a speed-gun used to measure "how fast a ball is thrown" in sporting codes

(4f). The example reinforces the presentational meaning of the scientific concepts and the concept of conversion between two types of motion. She also gestures, in the form of throwing a ball and swinging her arm, which has the affordance of showing what she explains in words about the motion. As previously highlighted, she uses the affordance of verbal language by using descriptive language for concepts interchangeably with the formal scientific concept names to develop conceptual meaning. She used descriptions such as “how fast a ball is thrown”, “how fast they were swinging the arm”, and then the scientific term “velocity” of the ball.

The lecturer explained in the interview that when she started teaching the physics module of the course, she considered the examples used in the existing course. She reported often thinking, “this is so irrelevant”, but also explained that she doesn’t “shy away” from examples that students “wouldn’t have encountered”. In the interview, she explained that she mitigates this challenge by combining her verbal explanations with other modes to facilitate student understanding of concepts. She explains, “I just try to give enough diagrams and draw stuff in, so that they can read and fully understand”. She also explained that generally she has to organise her teaching in a way that everybody understands: “something that is maybe really easy to me is really hard for them and I have to teach it in a way that everyone understands...I have to teach it in a kind of structured way.”

A student shared that the lecturer’s drawings were “very helpful” and “I don’t think you can do questions in physics without drawings because then you don’t understand what’s going on. It helps you know where to insert your values and gives you a picture in your brain.” These statements highlight the affordance of images to develop conceptual understanding.

Following her explanation of the concept of conversion in the lecture, the lecturer proceeds to use the symbolic conversion equations for linear displacement, linear velocity, and linear acceleration to give meaning to the mathematical procedure of conversion. She starts her explanation of the procedure using the equation for angular displacement taught in Excerpt 1. She manipulates this equation mathematically to give the conversion equation (Chapter 3 sections 3.2.2 & 3.2.3) for displacement. She then writes down the conversion equation for velocity and acceleration (Figure 5.8).

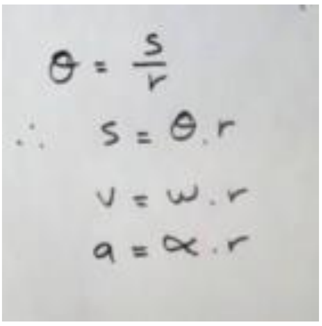


Figure 5.8 Conversion equations

5.7 Excerpt 5: Tangential velocity example

Following the explanation of the conversion equations (5.2.4), the lecturer gives the students a problem-solving example that requires them to use the conversion equations (which she has written on the board, Figure 5.8) to convert from angular velocity to linear velocity.

The lecturer starts by verbally stating:

> David uses a slingshot to slay Goliath. If the length of the slingshot strap was 90 centimetres and David spun the slingshot around at six revolutions per second, determine the tangential velocity of the tip of the slingshot i.e., the velocity at which the stone would have been released?

Then, at the macro-organisational level, she shows students how to solve the problem by taking parts of the information in the word-problem and providing the conceptual meanings linked to the different parts of the information. She then links the numerical values given in the word-problem to the concepts she identified and gave meaning to. Then she solves for angular velocity using the relevant conversion equation. Of particular interest in this excerpt is how she gives procedural meaning by using the modes to organise the conceptual meaning and link the numerical value to the concepts. Her spontaneous use of an object offers the affordance of a visual image of the concept ‘radius’ and a visual demonstration of the motion of the slingshot (i.e. radius in motion).

In the interview, she explained her choice of this example: “The reason why this example is nice is ’cos, although the terminology might be tricky, the actual example is a beautiful example of just really simple angular motion.” Her motivated choice indicates that she was aware that there was a need to attend to disciplinary language in this example but valued the example because it allowed her to apply angular motion concepts to problem-solving in a "simple" way.

<u>Excerpt 5</u>

5a So, what we're saying is, (***draws** a stick figure of slingshot strap and stone*) he is swinging it, there's the stone, **(d*raws*** *an arrow below the strap of the slingshot, labels it with 90cm*) that is 90 centimetres. And he is spinning it at (***draws** in a curved arrow above the strap of the slingshot labels it* '$\omega = 6rev/sec$') a velocity of 6 revolutions per second (Figure 4.8).

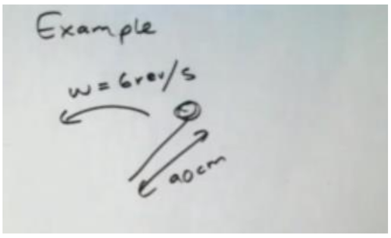


Figure 5.9 Slingshot drawing

5b So, revolutions per second. This is also new to you guys. Have you heard of revolutions per second before? You might have heard of rpm? If you've driven, in your car you have a little rev counter, it measures rpm (***writes** rpm = revolutions per minute, Figure 4.9*). Rpm is revolutions per minute. Ok, we're now working with revolutions per second.

5c How many degrees is one revolution? (Student response inaudible). How many radians is one revolution? (Student: 2pi) (**writes** 1rev=2π rad). So, what I want to know is, what is the velocity? **(*writes*** *'v?'*) [she gives students 3 minutes to solve for angular velocity]

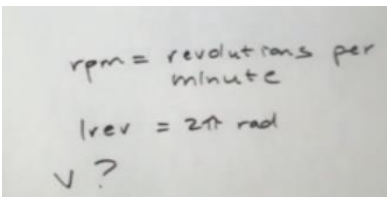


Figure 5.10 Revolutions per min

5d Ok. So, the first thing we want to do. We obviously want to convert these things to useful units. So, a lot of you started with omega. So, omega is equal to 6 revs per second **(*writes*** $\omega = 6\ \frac{rev}{s}$) and we said one rev is equal to 2 pi radians (*continues to* ***write*** $\omega = 6\ \frac{rev}{s} x \frac{2\,\pi\, rad}{1rev}$).

5e And you gonna see that we gonna cancel out our revolutions (***draws*** *a red line through 'rev' in the equation, Figure 4.10*) and we going to have 12 pi rad per second (***writes*** *12πrad/ sec*). Ok, if you wanna convert that to a value, whatever 12 times pi is, that's fine, you can write it as that as well. Not a problem. But it's quite easy. Your calculator likes to give you the answer as 12pi, and that is much easier to type in than whatever else it is going to give you. I like to leave it with the pi in there.

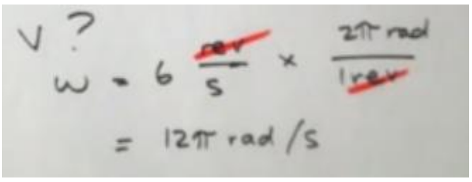


Figure 5.11 Angular velocity calculation

5f So the next thing we need to figure out is what is our 'r' value. So, we didn't talk too much about it. So, radius is normally from the centre of the circle to the edge (***gestures*** *a radius by holding out her arm*). So, if I was swinging a slingshot.

5g Does anybody have something I can swing? Just for visual purposes *(a student hands her a lanyard with a student card on one end).* Oh, that's such a good slingshot. So, if I'm swinging something (***holding*** *the lanyard at one end of the strap and with the student card hanging freely at the other end, she* ***swings*** *the lanyard in a circular motion in front of her*), where's the circle? On the outside right by the student card, right?

5h So, if I say that the strap of the student card is 90 centimetres long, would that be the radius or the diameter? (students: radius). So, the value I am giving you here is *this* length **(*holds*** *the lanyard and the student card at each end stretched out in a straight line).* From the centre of the circle to the edge of the circle. This was such a good visual. So, in this case this 90 centimetres equates to our radius.

5i So, in this case (***writes*** *r=90cm=0,9m*) radius is equal to 90 centimetres or I'm gonna write it as 0,9 metres. So, now we've got the two values that we were interested in. Now, let's work out 'v'.

5j We already have the equation we need to use. V is equal to omega times r, which is equal to 12 pi times 0,9 (***writes*** *v=* ω *r =(12* π*) (0.9)*). What did you get? You can write 54 over 5 pi. (***writes*** $\frac{54}{5}\pi\ m/s$), or you can write 33.9 (***writes*** *33,9m/s*), or (***writes*** *= 33,9*$m.s^{-1}$).

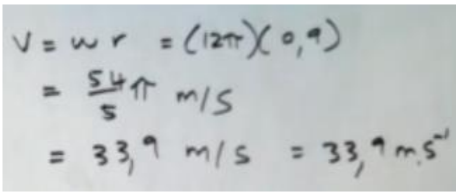


Figure 5.12 Solving for velocity

5k Whatever one you want to write generally, when we start going into linear, we don't leave the pi generally.

She demonstrates the first part of the problem-solving process by providing presentational meaning to the concepts and procedures. She organises this presentational meaning by first explaining the information and quantitative values in the word problem, using the appropriate verbal language choices before doing the problem-solving procedures. She gives presentational meaning to the "slingshot strap" as the concept radius, by representing it using a drawing of an iconic stick figure and labelling it "90cm", which is the value given in the word problem (5a, Figure 5.9). Then, she provides presentational meaning to the commonly used terms "swinging" and "spinning" for angular velocity by representing this motion using a symbolic curved arrow. She organises this meaning by labelling the curved arrow with the symbol 'ω' for the concept angular velocity, and labelling it with the numerical value, '$\omega = 6rev/sec$' (5a, Figure 5.9). Next, she provides presentational meaning to the unit "revolutions per minute" by orienting students to its use in the "rev counter" of a car, which she says some may be familiar with (5b, Figure 5.10). She then verbally reminds students that they need to solve for “velocity” and writes the symbol ‘v?’ (5b, Figure 5.11). But, before she solves for ‘v’, she signals through her questioning that they need to do unit conversion (5c). She then states that they need to convert the unit to “useful units” (5d). She uses the chain-link method and illustrates the process to convert from rev/min to radians/sec (5e, Figure 5.11).

Thus far in the first part of the lecturer’s problem-solving process, we see that she has given conceptual meaning to the information in the word problem. She related the problem information to its concepts of radius, angular velocity, and revolutions. She has also linked each of these concepts with its numerical value, that she will use in the procedural part of the problem-solving process. But before showing them the procedural steps, she gives meaning to the concept of radius ‘r’ and its numerical value using an object (5f).

She organises this meaning by linking it to the “slingshot strap” that she gave presentational meaning to earlier (5a). Acknowledging that they did not spend much time discussing the radius, she proceeds to use the affordances of combining modes to explain the concept of radius in relation to the word problem (5f). She begins this by descriptively explaining the concept ‘radius’ as extending “from the centre of the circle to the edge**”** (5f). Next, she represents the ‘radius’ using an iconic gesture by extending her right arm horizontally, and then combines this with an indexical gesture by running the index finger of her left hand along her extended arm from the shoulder (representing the centre) to the wrist (the edge of the circle) (5f). She then asks students if anybody has something to swing and is offered a lanyard attached to a student’s institutional identity card, as an object to use (5g). She then uses the lanyard in a spontaneous way as an object in motion to provide a demonstration mimicking the motion of a slingshot (5g). As she spins the lanyard, she first helps students identify the circle (5g), described verbally as being on the “outside”. She then helps students identify the “radius”. For this, she indicates that the lanyard strap represents the “radius” which, in relation to the problem, would have the value of “90 cm” (5h). This she indicates will be represented as “0.9m” when substituting the value into the equation (5i). This representation of an object in motion shows the “radius”, but importantly also illustrates the motion of the radius mimicking the “spinning” or “velocity”, which offers enhanced meaning in relation to the motion in the problem.

An interviewed student shared how the visual demonstration with the lanyard aided their understanding of the radius: “It was helpful to see the radius in something right in front of us. It helped us to understand the concept”. Another student reflected on the use of the lanyard, saying that it provided “better understanding than just drawing an arrow to the edge of the circle”.

Lastly in the lecture, she gives presentational meaning to the final step in the process of solving for velocity by focusing on the mathematical procedures of the problem-solving. She reminded students that they “already have an equation” (5j, Figure 5.12) to use as she writes out the conversion equation for linear velocity ‘$v = \omega\ r$.’ She then reads the symbols in the equation using the symbolic names and substitutes the symbols ‘ω’ and ‘r’ (5j, Figure 5.12) with their numerical values she gave meaning to earlier (5a-5i). She writes that the answer is ‘$\frac{54}{5}\pi\ m/s$’, but says they can write out the final answer as ‘33.9m/s or 33.9ms^{-1}’. She gives presentational meaning to linear velocity and orientational meaning to the appropriate way of representing the answer by taking a stance and saying, “when we start going into linear, we don’t leave the pi” (5k). She also provides important orientational meaning using the pronoun “we” to position students as members of the physics discipline applying its conventions in the problem-solving steps in their assessments.

Upon reflecting on this “beautiful” problem-solving example in the interview, the lecturer explained the usefulness of the example. She recognised the affordance of the object she used, that she described as an “easy visual”. The object and the use of other modes such as drawings and gesture, allowed her to represent concepts and the motion in the problem visually, to aid understanding:

> Just have the string and you have your object moving and it’s an easy visual. And it’s very simple in terms of ‘this is our point of rotation’. We have our string and then we have our object moving about at a certain velocity. And to determine all our values in this example is very easy to go, ‘Oh this is our radius, this is our point of rotation, that’s our omega.’ You know, it’s a very simple example and that is what’s nice about it.

5.8 Conclusion

In summary, the multimodal social semiotic analysis of the lecture excerpts showed how the lecturer planned the teaching and developed the meaning of the key concepts by first giving meaning to related concepts and linking the related concepts to give meaning to the key concept. She used a range of modes (summarised in Figure 5.1) individually and together to develop meaning. The lecturer interview analysis showed that she valued a sound conceptual and procedural understanding as well as the conceptual understanding related to problem-solving. It was also important to her to orientate students to the relevance of angular motion for physiotherapy. Her choices were grounded in these values and in her understanding of students' prior knowledge, the disciplinary conventions in the physics course, and the context that students may be involved in as future physiotherapists.

Her choices about her verbal talk showcased the specific way she used words to signal when students needed to draw on prior knowledge. She shifted between using scientific concept names and commonly used concept names or using words descriptively to provide students with access to conceptual meaning. Her choices related to other modes such as images, symbols and symbolic equations, written text, gestures, and the use of an object also indicated her understanding of the affordances of these different language modes. Moreover, the meaning she offered was enriched by linking various language modes to illustrate important relationships between these representations of concepts and procedures. The student extracts provided insight related to some excerpts explaining how the meaning she provided developed their understanding.

In Chapter 6, I present the discussion of these findings, the recommendations, and conclusions.

Chapter 6: Discussion, Recommendations and Conclusion

6.1 Introduction

The goal of this study was to explore a lecturer's use of multimodal language for meaning-making in pedagogy for the physics concept of angular motion in physiotherapy education.

As described in Chapter 1, this study responds to concerns raised by myself and colleagues about students' poor conceptual and procedural understanding necessary for problem-solving in physiotherapy. This problem is also reported in physiotherapy and physics education literature, which has demonstrated the importance of multimodal language and how this is used by lecturers to create opportunities for meaningful access, learning, and communication of concepts and procedures. In the context of my study, being able to procedurally solve angular motion physics problems is important within the physics classroom and assessments. However, a conceptual understanding while doing so is imperative because conceptual understanding is needed if students are to solve problems related to angular motion flexibly and to consider what that means when dealing with human movement in different contexts.

In this study, I used a multimodal social semiotic perspective that recognises the centrality of multimodal language for communicating and learning disciplinary meanings. This theoretical perspective allowed me to study a lecturers' *contextualised, motivated* use of multimodal language in *pedagogy* to give meaning to the v*alued conceptual and procedural knowledge* of angular motion required by *physiotherapy* students as future professionals. I used the following research questions to guide my inquiry:

1. How does the lecturer use multimodal language in a lecture to give meaning to the physics concept of angular motion?
2. What motivated the lecturer's choice of certain multimodal language use in the design of the teaching of the physics concept of angular motion?

Using multimodal social semiotic theory, and the tools developed for studying science (Lemke 1998a) and pedagogy in particular (Jaipal 2010; Kress et al. 2014; Fredlund et al. 2015), I devised the analytical framework for the study. It provided a lens through which to interpret and understand the lecturer's agentic, contextualised choices with respect to: how she organised her content and the multimodal language resources available to her (organisational meaning), how she used the affordances of language modes individually and together to give meaning to the concepts and procedures she taught (presentational meaning), the stance she took towards the content, and how she positioned students in relation to the content and context (orientational meaning). In particular, the attention to the orientational meaning of her pedagogy is important for studies of teaching and learning in professional degree programmes (Rayner 2005; Rennie & Parker 1993).

To situate my interpretations within the context of the lecturer's perspective, I begin with discussing her motivated choices (6.2 Research Question 2). Then, with this understanding, I move to how we see these enacted in her teaching practice (6.3 Research Question 1). Then, I present the limitations of the study (6.4) recommendations for practice (6.5), suggestions for further research (6.6) and conclusion (6.7).

6.2 Research Question 2: The lecturer's talk about her choices and related practice

Kress and Selander (2012) assert that choices to communicate meaning in a particular way are dependent on the person making the meanings and what they are intending to communicate. The analysis of the lecturer interview indicates that the lecturer's individual, contextualised pedagogical choices were motivated by:

- her knowledge of the angular motion concepts and the importance of developing students' conceptual and procedural understanding for physiotherapy practice
- her sense of her role as a lecturer in a professional physiotherapy degree programme, including the importance of motivating students to engage with the concepts of angular motion by positioning them as future physiotherapists
- her knowledge of the students' needs and resources in this context
- her experience and knowledge of teaching and her awareness of multimodal language use for meaning-making

During the interview, the lecturer expressed the importance of her pedagogy to develop students' understanding related to both the conceptual and procedural meaning of angular motion. The lecturer did this by following a specific pattern in her pedagogy by first giving meaning to the concepts, and then the symbols to be used in equations. When solving the problem procedurally, she first did the important work of unpacking the concepts specific to the problem-solving. The lecturer saw it as her role to develop students' understanding because she recognised differences between her own conceptual and procedural understanding, and that of first year students and therefore structured her teaching in a particular way. The lecturer's views align with physics education literature that argues for the importance of modelling problem-solving and to develop the conceptual understanding therefore (Huffman 1997; Gaigher 2006).

Recognising her role as a lecturer in a professional degree programme, the lecturer signalled her awareness that students may not have a comprehensive understanding of the physiotherapy profession at this early stage of their studies. It was important to her that students had opportunities to see the relevance of angular motion for their Physiotherapy course and practice as future physiotherapists, with these links also motivating students' engagement with physics concepts. This informed her decision to prioritise angular motion examples related to human movement (rather than other common examples such as spinning wheels). The lecturer's reported practice of deliberately contextualising physics is recommended in the literature, serving the dual purpose of orientating students to the links between the physics and the physiotherapy profession and motivating students' learning of physics (e.g., Ingerman et al. 2007; Rayner 2005).

The lecturer also had an understanding of students' diverse educational backgrounds and their resources, allowing her to thoughtfully draw on their prior learning of mathematics and physics. She reported drawing on similarities between concepts previously learned to develop meaning for concepts she introduced, such as using degrees as a foundation for radians. She indicated that she did this to show students that some of what they were learning was not totally 'new'.

The lecturer's talk about how and why she chose and used language modes suggests her awareness of the potential meaning-making affordances of these modes (Kress & Selander, 2012). Indeed, the use of language modes for meaning-making in physics pedagogy identified as important by researchers (e.g. Airey & Linder 2009; Fredlund et al. 2015; Le Roux & Kloot 2020; Tang et al. 2016; Van Heuwelen 1991). In my study, the lecturer explained that she used drawings, written text, and gestures 'to help them understand'. She said she used verbal talk to signal when and what prior knowledge students should draw on, and to signal important physics conventions. The lecturer also aimed to use her verbal talk strategically to facilitate students' understanding of scientific terms for conceptual understanding. She reported using the correct 'terminology' for symbols and symbol names, so that students could link concepts and become familiar with the symbols and symbolic equations, which is identified as a valuable strategy for developing students' understanding (Tang et al. 2016). Her choice to explain physics terms verbally was also based on her awareness that some students were learning in English as an additional language. This approach was also applied to problem-solving and she encouraged Physics tutors to similarly explain terminology, as it was important to her that students were able to relate meanings to problem-solving done in tutorials.

Kress et al (2014, p. 15) asserts that the teaching is an expression of the motivated choices from the meaning-making resources available to the teacher in a particular time and context. Therefore, I will now move to discuss the meanings the lecturer sought to develop and the available multimodal language resources she utilised to do so.

6.3 Research Question 1: How the lecturer uses multimodal language in a lecture to give meaning to the physics concept of angular motion

To understand how the lecturer communicated conceptual and procedural meaning to angular motion using the affordances of multimodal language, I begin with a discussion about how she organised her teaching (macro-organisational meaning) to provide presentational meaning to the concepts and procedures. Then at a micro-level, I focus on her use of modes to develop and organise this meaning. To illustrate these levels of organisation, I further develop the concept maps I used in section 3.2.3. Finally, I discuss how she used language modes to position students in relation to the content, orientating them to the contexts of physics and physiotherapy.

6.3.1 Macro-level organisation of lectures

At the macro-organisational level, the lecturer sequenced the lectures (figure 6.1 column 1) by first giving meaning to the key concept of angular displacement. Then, having established the concept of angular movement, she introduced the concept of angular velocity, the speed of this movement. And then, having established the concept of angular velocity, she introduced the concept of angular acceleration, the change in the speed of the angular movement over time. For each of these three key concepts, she introduced and explained its related concepts, illustrated the *links* between the related concepts, and demonstrated how these were procedurally applied (figure 6.1 column 2 and figure 6.2).

For example, to give meaning to angular displacement, the lecturer first gave meaning to circle concepts and showed the relationships between each circle concept. She explained the concept of radius (figure 6.2 - line A) in relation to the circle and circumference of the circle (figure 6.2 - line B), and then linked the arc length to the circumference (figure 6.2 Line C). Next, she showed the relationship between the radii and the arc length and explained that the angle (figure 6.2 - line D) subtended by the arc and the two radii was the angular displacement. Then, introducing the symbol for each concept she represented the relationship between the symbols in a mathematical equation (figure 6.2 - line E) for quantifying angular displacement. Thus overall, Illustrating and providing the conceptual links related to the equation, became the foundation for mathematical procedures and the problem-solving processes.

The lecturer's sequencing and linking of key concepts, related concepts, and mathematical procedures, while also orientating students to procedural conventions as described here, serves to organise the relationship of "the parts and the whole" (Lemke 1998, p. 251). Constructing this relationship between concepts, Kress et al. (2014, p. 23) assert, is important for the "shaping of knowledge".

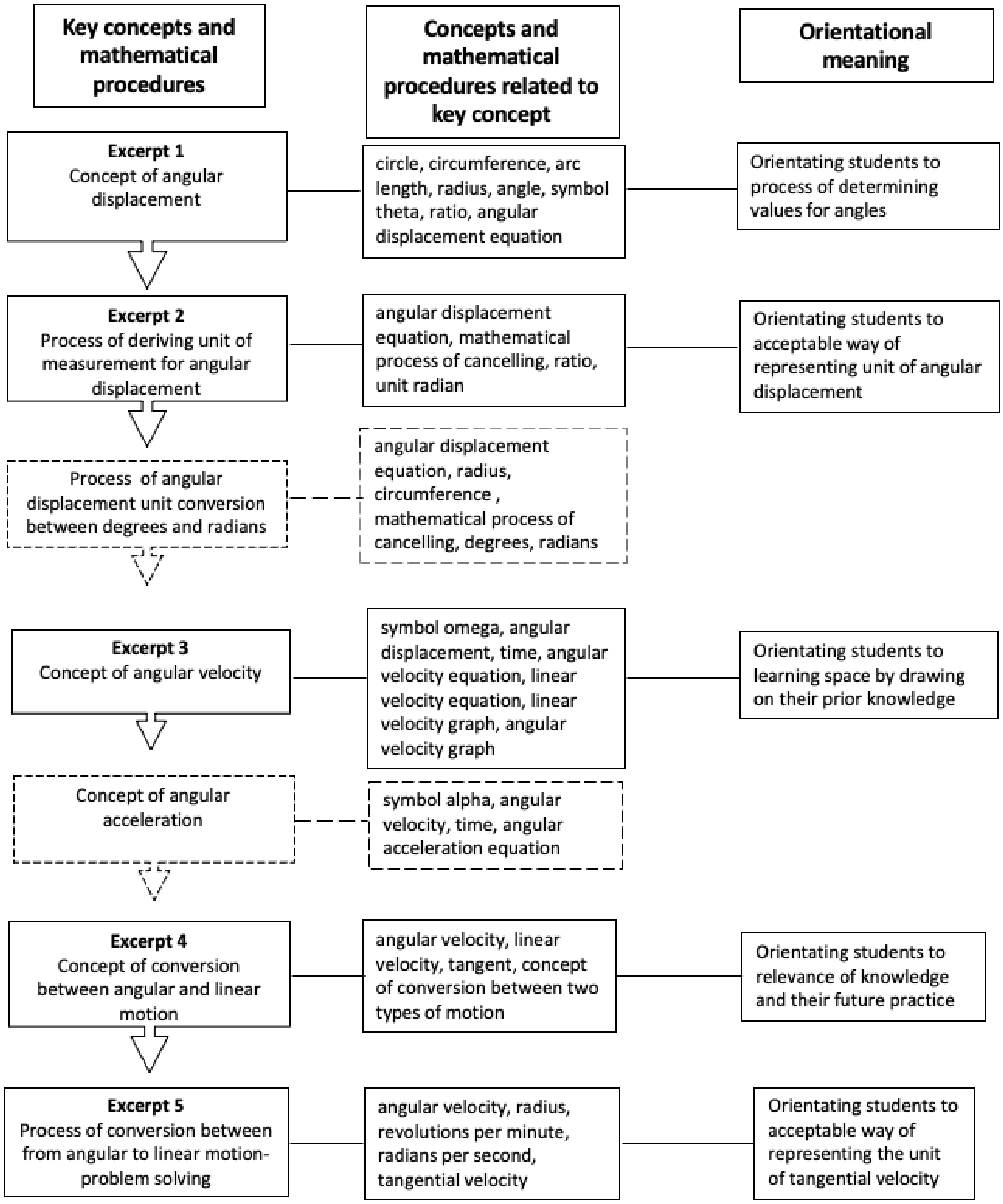


Figure 6.1 Key concepts, related concepts, and orientational meanings

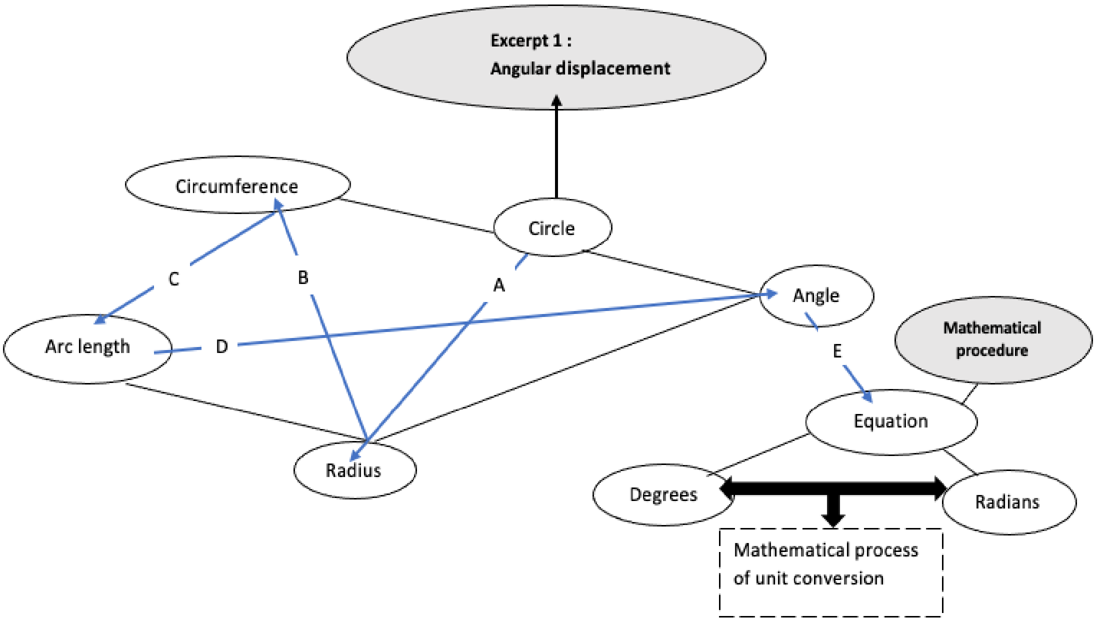


Figure 6.2 Organising meaning of angular displacement

The lecturer developed orientational meaning in three ways. Firstly, she orientated students towards physics conventions, thus modelling the acceptable ways of doing and thinking as physics students. For example, she explained the conventions for the unit of measurement for angular displacement (using students' mathematics knowledge of the process of cancelling) and tangential velocity (figure 6.1 excerpt 2 and 5, column C).

Secondly, the lecturer orientated students to their prior knowledge of linear motion and its relevance for understanding angular motion (figure 6.1 Excerpt 3). Thus, she positioned them as active participants expected to engage in the meaning-making process. She also took an orientational stance towards the knowledge as being familiar rather than novel, thus encouraging students to draw on their prior knowledge.

Thirdly, by choosing examples related to human movement, like swinging an arm or throwing a ball, she orientated these physiotherapy students to the relevance of their physics learning for their future clinical practice (figure 6.1 Excerpt 4). This is a practice identified by scholars as important for both learning and motivation to learn (e.g., Rayner 2005; Rennie & Parker 1993). Indeed, this practice was valued by a student in this physics course who did not study

Physical Science at school and expressed difficulty seeing the relevance of her university physics knowledge for physiotherapy.

6.3.2 Multimodal language to develop meaning

Having explored the meanings that the lecturer sought to develop, I will now discuss how, at the micro-organisational level, she used language modes to provide these meanings in her pedagogy. I focus on how she used the affordances of modes, specifically, verbal talk, written text, gestures, images, symbols and symbolic equations, and objects *in combination* to give meaning. I focus on selected examples from excerpts in chapter 5 to discuss her multimodal language use.

6.3.3 Integrating modes for meaningful procedures

Generally, the lecturer introduced each key concept by first focusing on conceptual meaning, using a combination of verbal talk, images, and gestures. Next, she tended to introduce symbols, integrating this into her verbal talk and through written symbols, strategically organised, in relation to the images and written text she had previously presented. This step appears to act as an important link between the conceptual and procedural, as it was generally followed by the introduction of the relevant symbolic equations of motion, into which she integrated the symbolic notation she had previously presented, allowing her to also focus on the procedural meanings.

For example, in her multimodal language use for the concept of arc length (figure 6.1, excerpt 1), the lecturer proceeded from an image of a circle to use verbal talk to describe the properties of arc length. Next, she used an iconic gesture which resembled an arc (Kress 2014), and then superimposed red colour on the image of the circle drawn on the board, thus visually calling attention to the arc and its length. Her combined use of verbal talk, gesture, and the use of colour on the circle image, linked arc length to the concepts of radii and the angle subtended by the arc and radii, thus developing conceptual meaning and creating the opportunity to introduce symbols and symbolic equations. She used verbal talk to name the concept 'arc length' and then wrote this name on the board, and then similarly introduced its symbol verbally by name and by writing it in symbolic notation. Strategic positioning of the written symbol for arc length next to the red highlighted arc (figure 5.2), had the affordance of showing the link between two representations of the same concept. The indexical image of an arrow (Harrison 2003) served as a cohesive device connecting the written word 'arc length' with its symbol 's' in the symbolic equation.

A symbolic equation, according to O'Halloran (2000), has the affordance of representing concepts in contracted form, including the complete relationship between concepts in the equation. The practice of providing the links between the symbols, symbolic equations, and the concepts they represent, is considered valuable for developing conceptual understanding (Sherin 2001). Importantly, in the example under discussion, the lecturer's attention to the symbols for the concepts of arc length and radius, laid the foundation to introduce the symbolic equation for angular displacement needed for problem-solving. Here the lecturer did the important work of first developing and providing conceptual meaning before introducing and representing it symbolically, in keeping with her intention to provide conceptual and procedural meaning.

6.3.4 The use of images, arrows, and an object to give meaning

In the interview the lecturer explained that she used images to aid her explanations and the meaning she intended to provide to the concepts. Her enactment of this involves starting with the images to represent concepts, and then using the images as a site for combining modes, such as written text and symbols, to develop conceptual meaning. She also uses images to help organise her meaning through how she positions different modes and concepts relative to one another. Thus, she sequentially develops her images, creating opportunities for students to visualise the links between the conceptual and procedural. To scaffold this discussion of her practice, I use the example of the concept of conversion.

To give meaning to the concept of conversion between two types of motion, she started by using an iconic drawing (Harrison 2003). She sequentially developed conceptual meaning by combining the language modes of symbols and symbolic arrows to relate concepts symbolically to the elements of her drawing (figures 5.7a-d). The symbolic arrows represented the two types of motion related to conversion, while the positioning of each symbolic arrow and the written symbols was an important way of organising the link between the motion of the arm and the motion of the ball. She used the shape of the arrows, a curved arrow for angular motion and a straight arrow for linear motion, to indicate the distinction between the two types of motion. Once students were familiar with the symbolic arrows and the concepts they represented, she used the combination of symbolic arrows, the iconic image, and written symbols as a link to providing procedural meaning.

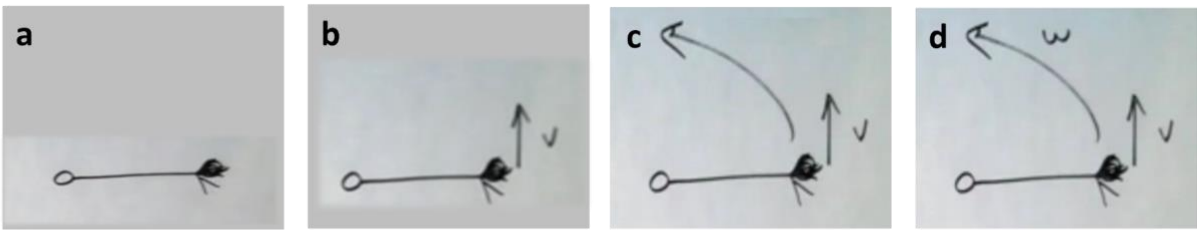


Figure 5.7 Different stages (a, b, c, d) showing ball in hand being thrown while arm moves in rotatory motion about the shoulder

Then in section 5.2.5, she applied the concept of conversion to a more complex problem example. While still using an example of an arm in motion, she added the element of a hand in motion, swinging an object (slingshot). Looking across the various images she drew, similarities become evident. The features of the iconic image of the arm and ball in hand (5.2.4), and the iconic image of a strap and stone (5.2.5) were similar. Her choice of human movement examples (rigid bodies rotating about a fixed axis), and being able to represent these through similar images, had the affordance of establishing a 'visual language' that students become familiar with. Additionally, similar images also had the affordance of aiding her with the transitioning from conceptual to procedural meaning in problem-solving.

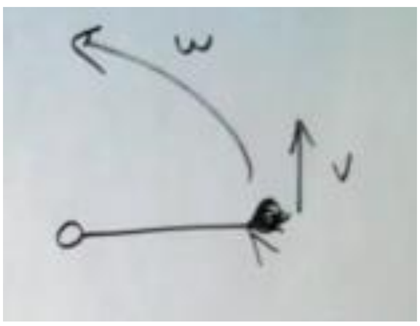


Figure 5.7d Angular velocity

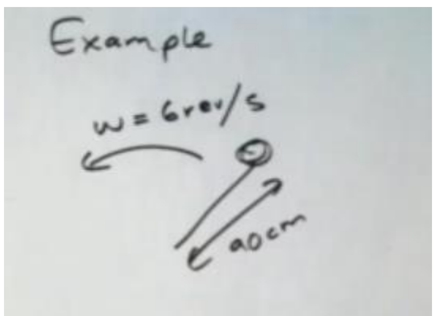


Figure 5.9 Slingshot drawing

In excerpt 5, the lecturer also used an object (lanyard and student card) to provide meaning to the concept of radius and angular motion as it related to the “slingshot” in the problem example. This is what Kress et al. (2014) terms an “object that mediates action”’, which has the affordance of bringing the concept, in this case radius and angular motion, into the classroom. The lecturer swung the lanyard mimicking the movement of the slingshot in an imaginary demonstration (Kress et al. 2014), making scientific properties of concepts apparent. The demonstration with the object had the affordance of showing the ‘radius’ (lanyard and student card) *and* showing the radius in motion.

The affordances of the images and the object that the lecturer used to provide meaning, were recognised by students. One commented that, ‘it gives you a picture in your brain’, while another reflected on the use of the object, saying that it provided a “better understanding than just drawing an arrow to the edge of the circle”.

6.3.5 Verbal talk for conceptual, organisational, and orientational meaning

The lecturer used her verbal talk intentionally to provide conceptual meaning, to organise the relationship between concepts and meanings, and to orientate students to the context of physics and physiotherapy.

For conceptual meaning, the lecturer used a purposeful combination of 'common' and scientific words to build on students' prior knowledge to facilitate access to new disciplinary knowledge (presentational). She shifted between explaining a concept descriptively, using the formal scientific concept names, and the more commonly used terms for these concepts. For example, she introduced the concept of tangential velocity using its formal scientific name, before giving meaning to it by using commonly used language (“*speed* of the ball in your hand”), then used descriptive language (“*how fast* a ball is thrown”). The affordance of using language in this interchangeable way to give meaning to scientific concepts has the potential to facilitate access to knowledge (Tang et al 2016) because, as argued by Lemke (2012), the meaning of any text depends on how it is connected to other texts.

The lecturer also used her verbal talk to organise content and signal to students when and what prior knowledge to draw on. For example, in section 5.2.3, her use of graphs and equations was accompanied by verbal talk such as ‘like’ and ‘similar to’. This established relations between the concept of angular velocity and the previously learned concept of linear velocity. Lemke (2012) refers to this use of verbal language as creating meaning relations between concepts.

For orientational meaning, the lecturer used her verbal talk, and the pronoun ‘we’ in particular, to position students as actors within the context (Lemke 2012). She also orientated students to the conventions in the physics course by taking a particular stance and communicating this stance by using phrases such as, “we don’t leave the pi generally” and “we normally represent it as…”. This act of orientating students to the important ways of knowing and doing is valuable for developing students’ disciplinary literacy in physics (Airey & Linder 2009).

6.4 Limitations of my study

This study is limited to one lecturers' pedagogy in a sequence of two Physics lectures for one concept that underpins the concept of rom in physiotherapy. Yet, as suggested by the discussion in sections 6.3 and 6.4, my in-depth attention to this lecturer’s multimodal pedagogy (RQ1) and her choices therefore (RQ2), within the constraints of a dissertation of this length, has yielded rich understandings of how the lecturer provided opportunities for learning in the study context. In this dissertation I have also offered a detailed description of this context, my theoretical concepts, and the operationalisation of these tools methodologically. As argued in section 4.4.3, this detail can inform how those in other contexts might use the empirical results and theoretical concepts. I end with insights for future practice (6.5) and research that builds on these findings (6.6).

6.5 Recommendations for practice

The multimodal social semiotics theory used in this study has alerted me to my own multimodal language use for meaning-making, and these learnings are already informing my teaching practice. Thus, I propose that the analytical tools used in this study could be used for planning and facilitating education development practice with lecturers. Crucially, this education development must work with the contextual and personal experience that a lecturer brings to the process.

Firstly, for physics lecturers teaching kinetics, there is value in using the tools to focus on the specific conceptual and procedural meanings that a lecturer intends to communicate, and how the pedagogy therefore may be organised at the macro-organisational levels. Secondly, education development with lecturers should include detailed attention to how various language modes can be used in combination to develop conceptual understanding of the necessary concepts of angular motion represented symbolically in problem-solving procedures. Indeed, any education development with lecturers who are disciplinary experts in physics and physiotherapy should include exploring the affordances of various language modes – verbal talk, written text, gesture, symbols and equations, and objects – for disciplinary meaning-making.

Through this exploration, lecturers are supported to make explicit how multimodal language is used to communicate disciplinary meaning, and hence to consider how their pedagogy may create opportunities for students to use language in these ways to access, learn and communicate meaning.

Finally, the concept of orientational meaning can be used in discussions between physics and physiotherapy lecturers about contextualising physics concepts in the wider physiotherapy curriculum and future physiotherapy practice. I propose that this includes collaborating on developing appropriate clinical cases and problem-solving tasks in which the physics is applied to the discipline of physiotherapy, and co-teaching to model problem-solving.

6.6 Further research

Given the rich insights afforded by the multimodal social semiotic theory (and related analytic tools in this study), I recommend the use of this perspective in three areas of research. Firstly, the perspective can be used to explore how lecturers use multimodal language for other physics concepts central to physiotherapy practice, for example, work-energy. Secondly, with reference to the recommended education development practice in section 6.5, as suggested by Jaipal (2010), research could focus on the use of the analytic framework (such as that used in my study) for planning of pedagogy with disciplinary lecturers.

The debates within the reviewed literature led me to focus my study on how and why a lecturer uses multimodal pedagogy to create opportunities for students to develop conceptual and procedural understanding of angular motion for physiotherapy. Thus thirdly, further research using a social semiotic multimodality perspective, should focus on how physiotherapy students themselves use multimodal language for meaning-making of angular motion.

6.7 Conclusion

In my study, I described what and how a lecturer used multimodal language to give meaning to the concept of angular motion, and I explained her pedagogical choices in the meaning-making process. The key findings showed that the lecturer's choices were aligned with her intention to provide conceptual meaning to angular motion for physiotherapy students and for that conceptual understanding to be applied to mathematical procedures when problem-solving. She enacted her intentions by following a specific pattern in her pedagogy that might be useful for consideration in other teaching contexts. Evident in her pedagogy was how she used the various language modes individually and together; carefully organising verbal talk, written text, gestures, symbols and symbolic equations, and the use of an object at a micro-level to relate conceptual and procedural meaning. Particularly noteworthy was the way that she utilised images and an object, to represent abstract conceptual meaning, and connect it directly to related procedural knowledge and problem-solving. Educational development opportunities should be created for lecturers to make explicit how they use multimodal language for disciplinary meaning, and to collaborate with other lecturers working in the same professional degree programmes to plan pedagogy that contextualises physics in physiotherapy.

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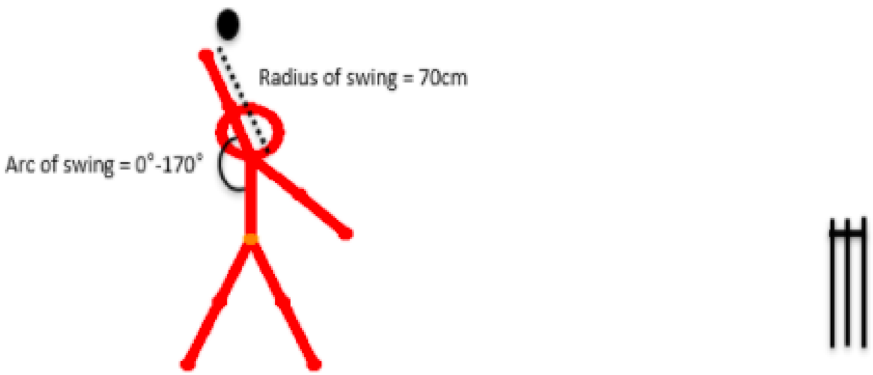
5. Appendices

a. Appendix A: Problem solution

Question:

A bowler is participating in a cricket fitness session. As part of his training he bowls in the cricket nets. While watching him bowl, you observe that he swings his right arm from 0° through an arc of 170° before the ball leaves his hand. The motion took 0.8 seconds. The radius of the swing was 70 cm.



1. Determine the angular acceleration of the bowler's arm during the motion.
2. Determine the final angular velocity of the bowler's arm just before the ball leaves his hand.
3. Determine the final linear velocity of the bowler's arm.

In the tables that follow, I guide you, the reader, through solving the problem to answer the three questions that were solved as part of the semi-structured interview (section 3.2.3)

Table 1 lists relevant information given in the problem text that a student needs to use to solve the problems. This includes the 'r'/ radius of the swing which is equal to 70cm. The process of unit conversion is required to convert the unit for the radius from centimetres to meters (row 1). The angular displacement value is given in degrees (row 2). Then in row 3, I show the process of converting the angular displacement unit from degrees to radians. Also given, is that the initial angular velocity is zero (row 4), and the time taken to release the ball is 0,8 seconds (row 5). These values are then substituted into the angular motion equation as shown in Table 2, to solve for angular acceleration. Table 3 and Table 4, show the procedure for solving final angular velocity and final linear velocity, respectively.

Table 1. Determining what is known related to the problem and necessary unit conversions

	Information given from word problem text	Key conceptual understanding	Related conceptual understanding	Procedural understanding
1.	r = 70 cm r= 0,7m	angular displacement	radius	Unit conversion
2.	$\Delta\theta = 170° - 0°$ = 170°		arc length	
3.	Conversion from degrees to radians $\Delta\theta = 170° X \frac{2\pi rad}{360°}$ $= \frac{17}{18}\pi\, rad$		degrees and radians as units of measurement	Unit conversion
4.	$\omega_i = 0$	angular velocity	initial angular velocity	
5.	t= 0,8s		time	

Solving for angular acceleration (Table 2), involves identifying the angular motion equation (row 1), manipulating the formula to make angular acceleration the subject of the equation (row 3), and then substituting (rows 2, 4) the known values (Table 1).

Table 2. Determining angular acceleration

	Process	Key conceptual understanding	Related conceptual understanding	Procedural understanding
1.	$\theta = \cancel{\omega_i t} + \frac{1}{2}\alpha t^2$			Chooses angular motion equation
2.	$\theta = \omega_i t + \frac{1}{2}\alpha t^2$		ω_i = zero therefore $\omega_i t$ = zero	
3.	$\therefore \theta = \frac{1}{2}\alpha t^2$ or $\therefore \alpha = \frac{2\theta}{t^2}$			Manipulating the equation making angular acceleration the subject
4.	$\therefore \alpha = \frac{2\left(\frac{17}{18}\pi\, rad\right)}{0{,}8\, sec^2}$ $\therefore \alpha = \frac{425}{144}\ \pi\, rad/sec^2$			Substituting with known values
5.	$\therefore \alpha = 9{,}27\ rad/sec^2$ (in the direction of the motion)	Angular acceleration	α is a vector quantity, has both magnitude and direction	

Table 3 shows the process of solving for final angular velocity. This involves first choosing the angular motion equation (row 1). Next, the value for angular acceleration determined in question 1 (Table 2, row 5), as well as the time value is substituted into the equation (row 2). Then final angular velocity is determined as shown in row 3.

Table 3. Determining the final angular velocity

	Process	Key conceptual understanding	Related conceptual understanding	Procedural understanding
1.	$\omega_f = \cancel{\omega_i} + \alpha t$		Initial velocity is zero	Chooses angular motion equation. Any number multiplied by zero is zero
2.	$\omega_f = \alpha t$ $\therefore \omega_f = (9.27 rad/s^2)(0{,}8\ s)$	Angular Velocity		Substituting with known values
3.	$\therefore \omega_f = 7.42$ rad/s (in the direction of the motion)		ω_f is a vector quantity, has both magnitude and direction	

Table 4 shows the process of determining the final linear velocity of the bowlers' arm. The first step is choosing the conversion equation for linear velocity (row 1). Then, the value for angular velocity (Table 3, row 3), and the value for the radius (Table 1, row 1), are substituted into the conversion equation (Table 4, row 1) to determine the final linear velocity.

Table 4. Determining the final linear velocity

	Process	Key conceptual understanding	Related conceptual understanding	Procedural understanding
1.	$v = \omega r$	Concept of conversion	Concept of a Tangential/linear velocity	Choosing conversion equation
2.	$= 7.42\ X\ 0{,}7$ $v = 5.19 m/s$ (tangent to the motion			Substituting known values.

b. Appendix B: Student data collection process

1. Recruitment and selection of students

Aiming to interview students with the diverse experiences and backgrounds represented in the first-year physiotherapy cohort of 43, I selected ten potential student participants using the Faculty Admission Status Report. Firstly, I included only students aged 18 years or older who were studying the Biosciences course and physiotherapy for the first time after completing schooling to grade 12 the year before. I then selected for diversity within this group using declared gender, having/not having studied Physical Sciences to grade 12, completed either English First Language or English Additional Language at school, and range of schools by quintile[2].

Eight of the ten invited students consented and participated. Seven participants were female, and one was male, from schools located in different geographical areas in South Africa. One student was from a quintile 5 school, four students were from quintile 4 schools, and three students were from quintile 1-3 schools. Two of the students did not do Physical Sciences at school. Five students completed English First Language and three students completed English Additional Language at school.

2. The three-part semi-structured student interviews

The 60-minute individual semi-structured student interviews each consisted of three parts. **Part one** consisted of the participants solving the same three problems on angular motion that the lecturer solved. I observed and made notes as they solved the problems. As student competence was not being assessed during the problem-solving process, it was important that students did not feel that they were being evaluated. Therefore, if a student struggled to solve the problem or missed an important step, I would prompt them using the record of the lecturer's problem-solving. This afforded me the opportunity to understand the nature of the difficulties the student was facing around conceptual and procedural understanding.

[2] School quintile is a government ranking of state schools by economic (dis)advantage of the geographical location, from quintile 5 ('wealthiest') to 1 ('poorest') (Hall & Giese 2008).

After they solved the problems, a "talk around text" (Lillis 2008, p. 355) followed, where I asked students about the problem-solving that I had observed. I probed to get insight into the students' conceptual and procedural understanding. Examples of questions I asked the students were: "Explain why you needed to convert from radians to degrees?" and "Explain what you understand by a tangent or tangential velocity?".

During **part two** of the semi-structured interview, I asked students about their schooling background, how having done (or not done) Physical Science at high school influenced their understanding or experience of university physics, what they found challenging about angular motion, and how they learned angular motion. In **part three**, students were shown six of the twelve video clips that I showed the lecturer so that I could explore how different modes used by the lecture contributed (or not) to their understanding of angular motion.

At the end of the interview, students were given an opportunity to add anything else they thought was relevant to the discussion, and they were free to ask me any questions about the study.

Student Interview Schedule

Introduction at beginning of Interview:

Please allow me to thank you once again for agreeing to participate in this study.

I want to remind you that all our discussions in this interview will be anonymous and treated confidentially. The data collected in this interview will be used for this research project only. The interview will be audio-recorded. My supervisors and I will be the only people accessing this recording. You may indicate if you prefer not to answer certain questions or end the interview at any stage.

This interview will be conducted in two parts. In part one, you will solve a typical physics problem on angular motion. Please write down all the steps you will follow to answer the question. I will also ask you to talk me through the steps you took to solve the problem.

In part two, I will ask you a few questions about yourself and then I focus on the lectures I observed and will ask you to answer questions about that.

Before we begin, do you have any questions about the study?

Part 1: Problem to be solved

Equations of motion

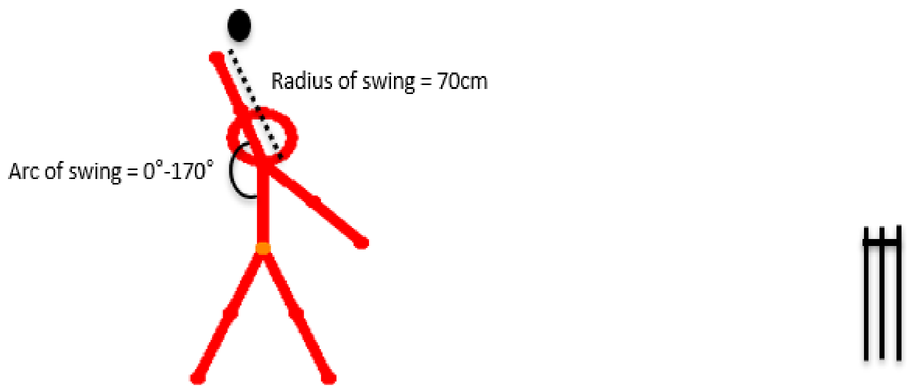
$$v = u + at \qquad \omega = \omega_0 + \alpha t$$

$$s = ut + \tfrac{1}{2}at^2 \qquad \theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$$

$$v^2 = u^2 + 2as \qquad \omega^2 = \omega_0^{\,2} + 2\alpha\theta$$

Question

A bowler is participating in a cricket fitness session . As part of his training he bowls in the cricket nets. While watching him bowl, you observe that he swings his right arm from 0° through an arc of 170° before the ball leaves his hand. The motion took 0.8 seconds. The radius of the swing was 70cm.



a) Determine the angular acceleration of the bowler's arm during the motion.
b) Determine the final angular velocity of the bowler's arm just before the ball leaves his hand.
c) Determine the final linear velocity of the bowler's arm.

Follow up questions on problem-solving task:

1. Please talk me through how you solved the problem?
2. What was the hardest/easiest part of ...?
3. What was the hardest/easiest part of solving the problem?

Proposed semi-structured interview questions with the student:

1. What language did you speak growing up?
2. What language did the science or maths teacher speak at school?
    i) In what ways has your language background helped or hindered your learning of physics at university?
3. Did you do physics in grade 12?
    i) In what ways has your experience of learning physics helped or hindered your learning of physics at university?

    Or

    ii) Do you think the fact that you did not study physics to matric has affected your studies at [name of university]? How have you responded to the challenge?

Let’s talk about the lecture

4. What do you think you were expected to know as key concepts before going into the lecture on angular motion?
5. Were you confident that you understood the concepts you named in question 4? How do you know?
6. Can you tell me what part of angular motion you find challenging?
    - Prompt: some people find angular displacement, or angular velocity or perhaps angular acceleration difficult to understand
7. What do you do during the lecture that helps you learn?
8. What do you do after the lecture that helps you learn?
9. What do you do when you get “stuck” and you find something hard to understand or do**?**
10. What do you think helps you understand an abstract concept such as……….., best?
11. When observing the lecture, I noticed that the lecturer introduced angular displacement by first doing (*insert text based on lecture observation*) then moving on to (b) then (c).
    i) Was this helpful?
    ii) Can you explain why you say so?

12. What helped you most in the way that it was explained?
13. Did you find the example on angular displacement helpful? Please explain.
14. Did you find the example on angular velocity helpful? Please explain.
15. Did you find the example on angular acceleration helpful? Please explain.
16. Is there anything that was covered in the lecture that you still find challenging?
17. What do you think will help you with your understanding of that?

Thank you for your time and participation. Do you want to add anything, or ask any further questions about the study?

c. Appendix C: Lecturer semi-structured interview schedule

Lecturer Interview Schedule

Introduction at beginning of Interview:

Please allow me to thank you once again for agreeing to participate in this study.

I want to remind you that all our discussions in this interview will be anonymous and treated confidentially. The data collected in this interview will be used for this research project only. The interview will be audio-recorded. My supervisors and I will be the only people accessing this recording. You may indicate if you prefer not to answer certain questions.

This interview will be conducted in two parts. In part one, you will solve a typical physics problem on angular motion. Please write down all the steps you will follow to answer the question. I will also ask you to talk me through the steps you took to solve the problem.

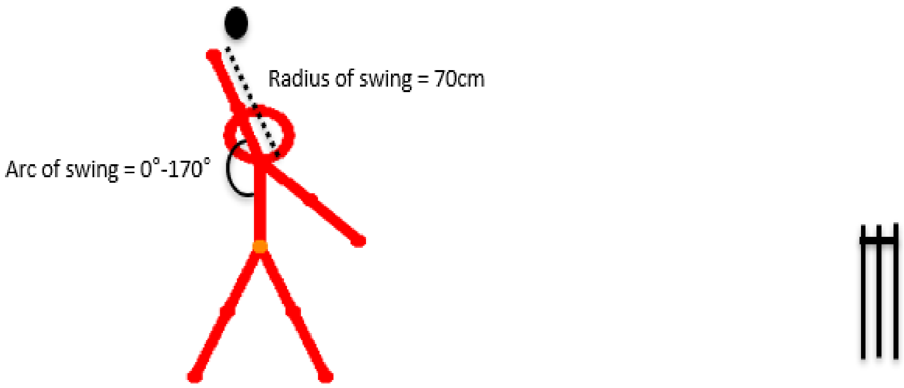
In part two, I will ask you some background questions and focus on the lectures I observed and will ask you to answer questions about that.

Equations of motion

$v = u + at$	$\omega = \omega_0 + \alpha t$
$s = ut + \frac{1}{2}at^2$	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$v^2 = u^2 + 2as$	$\omega^2 = \omega_0^{\ 2} + 2\alpha\theta$

Question

A bowler is participating in a cricket fitness session. As part of his training he bowls in the cricket nets. While watching him bowl, you observe that he swings his right arm from 0° through an arc of 170° before the ball leaves his hand. The motion took 0.8 seconds. The radius of the swing was 70cm.



a) Determine the angular acceleration of the bowler's arm during the motion.
b) Determine the final angular velocity of the bowler's arm just before the ball leaves his hand.
c) Determine the final linear velocity of the bowler's arm.

Follow-up questions on problem-solving tasks:

1. Can you talk me through how you solved the problem?
2. Where might a student have difficulty when solving this problem?
3. Why might they have this difficulty?

Proposed semi-structured Interview questions with the lecturer:

1. What did you intend students learn from this lecture?
2. What previous concepts do the concepts in this lecture build on?
3. Where will students have learnt these concepts?
4. How long have you been teaching this module as a whole?
   i) If you taught this module in previous years, how has your teaching developed on this concept over the years –
   Probe: what have you added, removed, or changed and why?
5. Please describe your planning of this lecture.
   Probe: What understandings the lecturer expected students to bring to the lecture. Any difficulties the lecturer expected the students to have, e.g., concepts related to angular displacement, angular velocity and angular acceleration)
6. Were their aspects of the lecture that you felt the students were struggling to grasp? Please give details.
   Probe: Lecturer's sense of what worked/did not work, and how she might have adapted.

Let's talk about specific parts of the lecture

7. I noticed that at the moment you (show in video) used this gesture. Can you explain your thinking about using this gesture?
8. When you explained the concept of ...(?), you drew a diagram with mathematical symbols as labels. What informed your choice at this moment?
9. I notice that you used this sequence "A - B – C" Why is this so?
10. A student asked about (*insert text from lecture observation)*. Then you erased ... and .... Again, can you explain your reasoning when responding in this way?
11. A student asked you a question about ….. You answered it by saying " ……" Can you tell me why you chose to explain it in that way?

12. You used these particular examples when you explained ….. concept. Can you tell me why you chose these examples?
13. I notice that you pointed out links between concept A and Concept B. Why did you do this?
14. I noticed that sometimes you unpacked certain concepts related to (x). Why did you decide to do that for concept (x), but not for concept (y)?
15. The linear equations of motion and angular equations of motion are analogous. What did you find helpful in explaining this to students?

Thank you for your time and participation. Do you have any questions or comments?

d. Appendix D: Information letter to Head of Department/Division/Programme

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Dear Head of Department, Head of Division, Head of Programme

My name is Sumaya Gabriels and I am a physiotherapist and lecturer in the [name of Department], and a postgraduate student at the [name of university]. As a requirement for my Masters Dissertation, I am conducting a research project. I have received ethical clearance for the study from the [name of] Research Ethics Committee as well as the [name of] Research Ethics Committee. The ethical principles of the Declaration of Helsinki have been applied.

The title of the research is: ***"A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."***

<u>An overview of the study</u>

This study will help us to understand how students learn and make meaning of angular motion, which in turn, may lead to new or enhanced ways to teach this concept and improve student learning.

The study has been designed in three parts and an overview is provided here.

Part one: Observation of lectures on angular motion.

During these lectures, the constructs of angular motion will be covered. I will attend the lectures as an observer, which means that I will not participate in the lectures or classroom activity in any way. The purpose of my observation will be to understand how the lecturer teaches these concepts and what kinds of representational resources are used (for example, equations, graphs, diagrams etc…). My focus will be on what the lecturer does, and my understanding will be strengthened by noting what questions students may ask for clarity, specifically regarding their understanding of the representational resources.

After the lectures, I will have access to the video recording of the lectures. This, along with my notes, will be used to refine the questions for the semi-structured interview in part two of the study.

Part two: Problem-solving and semi-structured interview with the lecturer

During this part of the study, I will ask the lecturer to solve a typical angular-motion physics problem (the same problem will be given to the students in part 3), and then talk me through the process. The purpose of this is to understand how an expert approaches solving the problem. The semi-structured interview will follow and will focus on the lecture observed during part 1. The purpose of this is to understand the reasons for the choices the lecturer made in planning and delivering the lectures, with a particular focus on the representation resources used.

Part three: Problem-solving and semi-structured interviews with students

For this part of the study, twenty students will be pre-selected based on in- and exclusion criteria. Given my overall interest in improving teaching and learning in the course, the selection will reflect the diversity of the class in terms of gender, language repertoire, and school background. Of the twenty pre-selected, ten students will be invited to participate in individual interviews. During the session, I will ask students to solve a typical angular-motion physics problem (the same problem will be given to the lecturer in part 2), and then ask them to talk me through the process. The purpose of this is to help me understand how a student approaches solving the problem. The semi-structured interview will follow and will focus on the lecture observed during part 1. The purpose of this is to understand how the representational resources used in the lectures contributed to their understanding of angular motion. Students will also be asked about what strategies they use to facilitate their learning of angular motion concepts.

What will the participation involve for lecturer and students?

As explained in part one, I will be an observer during the lectures on angular motion. I will also watch, transcribe and analyse the lecture recording. In other words, the lecturer will not be asked to do anything, other than to consent to being observed. I will be making notes of any questions the students ask and on how the lecturer responds to those questions using multimodal representations.

As explained in part 2, during the 60 minute semi-structured interview, the lecturer will be required to:

- solve a typical angular motion physics problem,
- talk me through the problem-solving process,
- tell me about the intended outcomes for the lecture,
- answer questions about the choices made in planning and
- talk about delivering the lecture, with a particular focus on the representational resources used.

In part 3, during the 60-minute individual semi-structured interview, the students will be required to:

- solve a typical angular motion physics problem,
- talk me through the problem-solving process,
- answer some background questions on their schooling and home language,
- answer questions about their experience of the lecture in relation to the modes used and their learning strategies.

Participation is entirely voluntary. There is no penalty if participants choose not to participate Participation or non-participation will not affect students' marks in the course now or in the future in any way.

There is also no reward for participation, nor will there be any compensation. If participants do choose to participate, they may also choose not to answer particular questions. They will be required to give written consent to participate in the study.

Privacy and Confidentiality

All the information collected will be treated confidentially. Only my two supervisors will have access to the data. Individual privacy and confidentiality of data will be protected. Pseudonyms will be used in the academic reports arising from the research, in academic presentations and journal articles. Hard-copy data will be safely stored in a locked cabinet in the [name of Department]. Only I will have access to the cabinet. Electronic copies of documents on my personal computer and hard drive will be password protected, which will be securely stored when not in use. After the study all soft and hard-copy documents, recordings and transcriptions will be destroyed and will not be used for any other study.

Risks and Benefits

There are no foreseeable risks to choosing to participate in this study. Participation and/or withdrawal from the study will not affect student participants' marks now or in the future in any way. The course lecturer and lecturers on other courses will not be involved in the selection of student participants and will not be aware of who has chosen to participate.

There are no direct benefits for participating in the study, other than the knowledge that it will contribute to improving the teaching of physiotherapy students. There will be no payment or compensation for participating in the study.

Member checking

Where necessary, analysed data will be shared with participants to ensure that what they shared is accurately reflected. Participants will be contacted via email in this regard.

Questions and Concerns

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

Researcher: Sumaya Gabriels – [telephone number]

Supervisor: Dr Natashia Muna – [email address]

Co-Supervisor: Associate Professor Kate le Roux – [email address]

This research has been approved by the [name of] Research Ethics Committee and its reference number is [reference number]

You may also contact the [name of university] Research Ethics Committee if you have any questions or concerns about your rights and welfare as a research participant.

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Or

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Thank you

____

Sumaya Gabriels

e. Appendix E: Lecturer participant information sheet – observation of lecture

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Dear Participant

My name is Sumaya Gabriels and I am a physiotherapist and lecturer in the [name of Department], and a postgraduate student at the [name of university]. As a requirement for my Masters Dissertation I am conducting a research project. I have received ethical clearance for the study from the [name of] Research Ethics Committee as well as the [name of] Research Ethics Committee. The ethical principles of the Declaration of Helsinki have been applied.

The title of the research is: ***"A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."***

You are being invited to participate in this study because you are the lecturer of the Physics module of the [name of course].

An overview of the study

This study will help us to understand how students learn and make meaning of angular motion, which in turn may lead to new or enhanced ways to teach this concept and improve student learning. The study has been designed in three parts, an overview is provided here. You are being invited to participate in ***part one*** and ***part two*** of the study.

Part one: Observation of a lectures on angular motion.

During these lectures, the constructs of angular motion will be covered. I will attend the lectures as an observer, which means that I will not participate in the lectures or classroom activity in any way. The purpose of my observation will be to understand how these concepts are taught and what kinds of representational resources are used (for example, equations, graphs, diagrams etc…). I will take notes during the observation, including questions that students may ask for clarity, specifically regarding their understanding of the representational resources.

After the lectures, I would like to have access to the video recording of the lectures. This, along with my notes, will be used to refine the questions for the semi-structured interview in part two of the study.

Part two: Problem-solving and semi-structured interview with the lecturer.

You will be involved in ***part 1*** and ***part 2*** of the study. **You will be asked to formally consent to part 2 of the study on the day of the interview.**

What will your participation involve in part 1?

As explained in part 1, I will be an observer during your lectures. I will also watch, transcribe, and analyse the lecture recordings. In other words, you will not be asked to do anything, other than to consent to being observed.

Your participation is entirely voluntary. There is no penalty if you choose not to participate or if you do choose to participate. Your participation or non-participation will not affect you now or in the future in any way. There is also no reward for participation. If you do choose to participate, you may also choose not to answer particular questions in the interview. You may also stop the interview at any time and/or withdraw completely from the study. You will be required to give your written consent to participate in the study.

Privacy and Confidentiality

All the information collected will be treated confidentially. Only my two supervisors will have access to the data. Individual privacy and confidentiality of data will be protected. Pseudonyms will be used in the academic reports arising from the research, in academic presentations and journal articles. Hard-copy data will be safely stored in a locked cabinet in the [name of Department]. Only I will have access to the cabinet. Electronic copies of documents on my personal computer and hard drive will be password protected, which will be securely stored when not in use. After the study all soft and hard-copy documents, recordings and transcriptions will be destroyed and will not be used for any other study.

I acknowledge that because this is a small-scale study and you are the only physics lecturer, there is a risk that you may be identifiable. I would like to assure you that in the writing of the report or in any presentations, I will remain true to the aim of the study which is to explore and understand how multimodal representations are used in the teaching and learning of the concept of angular motion, with the ultimate goal of improving teaching and learning for all. I will seek the assistance of my supervisors in this regard.

Risks and Benefits

There are no foreseeable risks to you by choosing to participate in this study.

There are no direct benefits to you for participating in the study, other than the knowledge that your participation will contribute to improving the teaching of physiotherapy students. You will not be paid or compensated for participating in the study.

Member checking

Where necessary analysed data will be shared with you to ensure that what you shared is accurately reflected. You will be contacted via email in this regard.

Questions and Concerns

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

Researcher: Sumaya Gabriels – [telephone number]

Supervisor: Dr Natashia Muna – [email address]

Co-Supervisor: Associate Professor Kate le Roux – [email address]

This research has been approved by the [name of] Research Ethics Committee and its reference number is [reference number]

You may also contact the [name of university] Research Ethics Committee if you have any questions or concerns about your rights and welfare as a research participant.

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Or

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Please indicate that you understand what is required of you and that you are willing to participate in the study by signing the consent form on the following page.

Thank you

____

Sumaya Gabriels

f. Appendix F: Lecturer consent form for observation

Dear Lecturer

Kindly indicate for each statement listed whether you agree or disagree by circling your choice:

I consent to participating in part 1 of the study: Researcher observation of lectures on angular motion	**Yes / No**
I consent to the researcher accessing the recordings of the lectures on the course Learning Management Site	**Yes / No**
I know that I may choose not to answer specific questions and I may choose to withdraw from the study at any time,	**Yes / No**
I know that I can contact the researcher or supervisors at any time if I have any questions.	**Yes/ No**
I know that I can contact the [name of] Research Ethics Committee or [name of] Research Ethics committee at any time if I have any questions about my rights or welfare as a research participant.	**Yes / No**

I, ____ voluntarily consent to participate (as indicated in the table above) in this part of the research project titled "*A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education.*"

Signed:

____________________________ ____________________________

Participant date and place

____________________________ ____________________________

Witness date and place

g. Appendix G: Student participant information sheet for observation of lecture

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Dear Participant

My name is Sumaya Gabriels and I am a physiotherapist and lecturer in the [name of Department], and a postgraduate student at the [name of university]. As a requirement for my Masters Dissertation I am conducting a research project. I have received ethical clearance for the study from the [name of] Research Ethics Committee as well as the [name of] Research Ethics Committee. The ethical principles of the Declaration of Helsinki have been applied.

The title of the research is: ***"A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."***

<u>An overview of the study</u>

This study will help us to understand how students learn and make meaning of angular motion, which in turn may lead to new or enhanced ways to teach this concept and improve student learning. The study has been designed in three parts and an overview is provided here.

Part one: Observation of a lectures on angular motion.

During these lectures, the constructs of angular motion will be covered. I will attend the lectures as an observer, which means that I will not participate in the lectures or classroom activity in any way. The purpose of my observation will be to understand how the lecturer teaches these concepts and what kinds of representational resources are used (for example, equations, graphs, diagrams etc…). My focus will be on what the lecturer does, but my understanding will be strengthened by noting what questions students may ask for clarity, specifically regarding their understanding of the representational resources.

After the lectures, I will have access to the video recording of the lectures. This, along with my notes, will be used to refine the questions for the semi-structured interview in Part two of the study.

Part three: Problem-solving and semi-structured interviews with students

Students will be invited via email to participate in a one-hour interview You will sign a separate consent form for this part 3, should you be selected and invited to participate in this part of the study.

What will your participation involve in the observation?

As explained, I will be an observer during your lectures. I will also watch, transcribe, and analyse the lecture recording. In other words, you will not be asked to do anything, other than to consent to being observed. I will be making notes of any questions you ask but the focus will be on how the lecturer responds to your question.

Your participation is entirely voluntary. There is no penalty if you choose not to participate, or if you do choose to participate. Your participation or non-participation will not affect your marks in the course now or in the future in any way.

There is also no reward for participation, nor will there be any compensation. If you do choose to participate, you may also choose not to answer particular questions. You will be required to give your written consent to participate in the study.

Privacy and Confidentiality

All the information collected will be treated confidentially. Only my two supervisors will have access to the data. Individual privacy and confidentiality of data will be protected. Pseudonyms will be used in the academic reports arising from the research, in academic presentations and journal articles. Hard-copy data will be safely stored in a locked cabinet in the [name of Department]. Only I will have access to the cabinet. Electronic copies of documents on my personal computer and hard drive will be password protected, which will be securely stored when not in use. After the study all soft and hard-copy documents, recordings and transcriptions will be destroyed and will not be used for any other study.

Risks and Benefits

There are no foreseeable risks to you by choosing to participate in this study. Your participation and/or withdrawal from the study will not affect your marks now or in the future in any way. The course lecturer and lecturers on other courses will not be involved in the selection of student participants and will not be aware of who has chosen to participate.

There are no direct benefits to you for participating in the study, other than the knowledge that your participation will contribute to improving the teaching of physiotherapy students. You will not be paid or compensated for participating in the study.

Member checking

Where necessary analysed data will be shared with you to ensure that what you shared is accurately reflected. You will be contacted via email in this regard.

Questions and Concerns

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

Researcher: Sumaya Gabriels – [telephone number]

Supervisor: Dr Natashia Muna – [email address]

Co-Supervisor: Associate Professor Kate le Roux – [email address]

This research has been approved by the [name of] Research Ethics Committee and its reference number is [reference number]

You may also contact the [name of university] Research Ethics Committee if you have any questions or concerns about your rights and welfare as a research participant.

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Or

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Please indicate that you understand what is required of you and that you are willing to participate in the study by signing the consent form on the following page.

Thank you

____

Sumaya Gabriels

h. Appendix H: Student participant consent form for observation of lecture

---

Dear Student

Kindly indicate for each statement listed whether you agree or disagree by circling your choice:

I consent to participating in part 1 of the study: Researcher observation of the lectures on angular motion	**Yes / No**
I consent to the researcher making field notes of any questions I may ask the lecturer.	**Yes / No**
I know that I can contact the researcher or supervisors at any time if I have any questions.	**Yes/ No**
I know that I can contact the [name of] Research Ethics Committee or [name of] Ethics committee at any time if I have any questions about my rights or welfare as a research participant	**Yes / No**

I, ____ voluntarily consent to participate (as indicated in the table above) in this part of the research project titled "*A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education.*"

Signed:

______________________________ ____________________________

Participant date and place

______________________________ ____________________________

Witness date and place

i. Appendix I: Lecturer participant information sheet for semi-structured interview

Dear Participant

My name is Sumaya Gabriels and I am a physiotherapist and lecturer in the [name of Department], and a postgraduate student at the [name of university]. As a requirement for my Masters Dissertation I am conducting a research project. I have received ethical clearance for the study from the [name of] Research Ethics Committee as well as the [name of] Research Ethics Committee. The ethical principles of the Declaration of Helsinki have been applied.

The title of the research is: ***"A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."***

You are being invited to participate in this study because you are the lecturer of the Physics module of the [name of] course.

<u>An overview of part 2 of the study</u>

Thank you for participating in part one of the study, the lecture observations. This information explains part two of the study for which I will need your written consent should you agree to participate.

Part two: Problem-solving and semi-structured interview with the lecturer

During this part of the study, I will ask you to solve a typical angular-motion physics problem (the same problem will be given to students in part 3), and then talk me through the process. The purpose of this is to understand how an expert approaches solving the problem. The semi-structured interview will follow and will focus on the lecture observed during part 1. The purpose of this is to understand the reasons for the choices you made in planning and delivering the lectures, with a particular focus on the representational resources used.

What will your participation involve?

You will participate in one interview only. It will be one hour long and take place in a tutorial room on campus, at a time convenient for you. In this part of the interview you will be required to:

- solve a typical angular motion physics problem,
- talk me through your problem-solving process,
- tell me about the intended outcomes for the lecture,
- answer questions about the choices you made in planning and
- talk about delivering the lecture, with a particular focus on the representational resources used.

Your participation is entirely voluntary. There is no penalty if you choose not to participate or if you do choose to participate. Your participation or non-participation will not affect you now or in the future in any way. There is also no reward for participation. If you do choose to participate, you may also choose not to answer particular questions in the interview. You may also stop the interview at any time and/or withdraw completely from the study. You will be required to give your written consent to participate in the study.

Privacy and Confidentiality

All the information collected will be treated confidentially. Only my two supervisors will have access to the data. Individual privacy and confidentiality of data will be protected. Pseudonyms will be used in the academic reports arising from the research, in academic presentations and journal articles. Hard-copy data will be safely stored in a locked cabinet in the [name of department]. Only I will have access to the cabinet. Electronic copies of documents on my personal computer and hard drive will be password protected, which will be securely stored when not in use. After the study all soft and hard-copy documents, recordings and transcriptions will be destroyed and will not be used for any other study.

I acknowledge that because this is a small-scale study and you are the only physics lecturer, there is a risk that you may be identifiable. I would like to assure you that in the writing of the report or in any presentations, I will remain true to the aim of the study which is to explore and understand how multimodal representations are used in the teaching and learning of the concept of angular motion, with the ultimate goal of improving teaching and learning for all. I will seek the assistance of my supervisors in this regard.

In any public communication about this study (such as my thesis, conference presentations or journal articles) all identifying data will be removed and participants will be anonymised using pseudonyms.

Risks and Benefits

There are no foreseeable risks to you by choosing to participate in this study.

There are no direct benefits to you for participating in the study, other than the knowledge that your participation will contribute to improving the teaching of physiotherapy students. You will not be paid or compensated for participating in the study.

Member checking

Where necessary analysed data will be shared with you to ensure that what you shared is accurately reflected. You will be contacted via email in this regard.

Questions and Concerns

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

Researcher: Sumaya Gabriels – [telephone number]

Supervisor: Dr Natashia Muna – [email address]

Co-Supervisor: Associate Professor Kate le Roux – [email address]

This research has been approved by the [name of] Research Ethics Committee and its reference number is

You may also contact the [name of university] Research Ethics Committee if you have any questions or concerns about your rights and welfare as a research participant.

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Or

Chair of [name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Please indicate that you understand what is required of you and that you are willing to participate in the study by signing the consent form on the following page.

Thank you

____

Sumaya Gabriels

j. Appendix J: Lecturer consent form for semi-structured interview

---

Dear Lecturer

Kindly indicate for each statement listed whether you agree or disagree by circling your choice:

I consent to participating in part 2 of the study: Solving a physics problem and a semi-structured interview	**Yes / No**
I consent to the researcher audio-recording the interview	**Yes / No**
I consent to submitting the completed worksheet to the researcher after the interview	**Yes/No**
I know that I may choose not to answer specific questions and I may choose to withdraw from the study at any time,	**Yes / No**
I know that I can contact the researcher or supervisors at any time if I have any questions.	**Yes/ No**
I know that I can contact the [name of] Research Ethics Committee or [name of] Research Ethics committee at any time if I have any questions about my rights or welfare as a research participant	**Yes / No**

I, ____ voluntarily consent to participate (as indicated in the table above) in this part of the research project titled "*A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education.*"

Signed:

____________________________ ____________________________

Participant date and place

____________________________ ____________________________

Witness date and place

k. Appendix K: Student participant information sheet for semi-structured interview

---

Dear Participant

My name is Sumaya Gabriels and I am a physiotherapist and lecturer in the [name of Department], and a postgraduate student at the [name of university]. As a requirement for my Masters Dissertation I am conducting a research project. I have received ethical clearance for the study from the [name of] Research Ethics Committee as well as the [name of] Research Ethics Committee. The ethical principles of the Declaration of Helsinki have been applied.

The title of the research is: ***"A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."***

An overview of part 3 of the study

This study will help us to understand how students learn and make meaning of angular motion, which in turn may lead to new or enhanced ways to teach this concept and improve student learning. The study has been designed in three parts and an overview is provided here.

Thank you for participating in part one of the study. We are now moving onto part 3 of the study. The information below explains this part of the study, and if you agree to participate in this part of the study you would have to consent in writing in the attached consent form.

Part three: Problem-solving and semi-structured interviews with students

For this part of the study, twenty students will be pre-selected based on in- and exclusion criteria. Given my overall interest in improving teaching and learning in the course, the selection will reflect the diversity of the class in terms of gender, language repertoire, and school background. Ten students will be invited to participate in the interview. During the session, I will ask you to solve a typical angular-motion physics problem (the same problem will be given to the lecturer in part 2), and then ask you to talk me through the process. The purpose of this is to help me understand how a student approaches solving the problem. The semi-structured interview will follow and will focus on the lecture observed during part 1. The purpose of this is to understand how the representational resources used in the lectures contributed to your understanding of angular motion. You will also be asked about what strategies you use to facilitate your learning of angular motion concepts.

What will your participation involve?

You will participate in one interview only. It will be one hour long and take place in a tutorial room on campus, at a time convenient for you. You will be required to:

- solve a typical angular motion physics problem,
- talk me through your problem-solving process,
- answer some background questions on your schooling and home language,
- answer questions about your experience of the lecture in relation to the modes used you're your learning strategies.

Your participation is entirely voluntary. There is no penalty if you choose not to participate or, if you do choose to participate. Your participation or non-participation will not affect your marks in the course now or in the future in any way.

There is also no reward for participation, nor will there be any compensation. If you do choose to participate, you may also choose not to answer particular questions. You will be required to give your written consent to participate in the study.

Privacy and Confidentiality

All the information collected will be treated confidentially. Only my two supervisors will have access to the data. Individual privacy and confidentiality of data will be protected. Pseudonyms will be used in the academic reports arising from the research, in academic presentations and journal articles. Hard-copy data will be safely stored in a locked cabinet in the [name of] Department. Only I will have access to the cabinet. Electronic copies of documents on my personal computer and hard drive will be password protected, which will be securely stored when not in use. After the study all soft and hard-copy documents, recordings and transcriptions will be destroyed and will not be used for any other study.

Risks and Benefits

There are no foreseeable risks to you by choosing to participate in this study. Your participation and/or withdrawal from the study will not affect your marks now or in the future in any way. The course lecturer and lecturers on other courses will not be involved in the selection of student participants and will not be aware of who has chosen to participate.

There are no direct benefits to you for participating in the study, other than the knowledge that your participation will contribute to improving the teaching of physiotherapy students. You will not be paid or compensated for participating in the study.

Member checking

Where necessary analysed data will be shared with you to ensure that what you shared is accurately reflected. You will be contacted via email in this regard.

Questions and Concerns

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

You are free to contact myself or either of my supervisors if you have any questions or concerns about this study.

Researcher: Sumaya Gabriels – [telephone number]

Supervisor: Dr Natashia Muna – [email address]

Co-Supervisor: Associate Professor Kate le Roux – [email address]

This research has been approved by the [name of] Research Ethics Committee and its reference number is [reference number]

You may also contact the [name of university] Research Ethics Committee if you have any questions or concerns about your rights and welfare as a research participant.

Chair of [name of] Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Or

Chair of [[name of] Research Ethics Committee: [name of chairperson], [telephone number], [email address of chairperson]

Please indicate that you understand what is required of you and that you are willing to participate in the study by signing the consent form on the following page.

Thank you

____

Sumaya Gabriels

I. Appendix L: Student participant consent form for semi-structured interview

Dear Student

Kindly indicate for each statement listed whether you agree or disagree by circling your choice:

I consent to participating in part 2 of the study: Solving a physics problem and a semi-structured interview.	**Yes / No**
I consent to the researcher audio-recording the interview.	**Yes / No**
I consent to submitting the completed worksheet to the researcher after the interview.	**Yes/ No**
I know that I can contact the researcher or supervisors at any time if I have any questions.	**Yes/ No**
I know that I can contact the [name of] Research Ethics Committee or [name of] Research Ethics committee at any time if I have any questions about my rights or welfare as a research participant.	**Yes / No**

I, ____ voluntarily consent to participate (as indicated in the table above) in this part of the research project titled "*A multimodal social semiotic analysis of lecturer pedagogy for the physics concept of angular motion in physiotherapy education."*

Signed:

______________________________ ____________________________

Participant date and place

______________________________ _____________________________

Witness date and place