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LONGITUDINAL DESIGNS AND THEIR CONTRIBUTION TO UNDERSTANDING LEARNING IN SCIENCE

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Relationships between teacher researcher and students in longitudinal design, and the complexity of learning

Introduction

As a practicing secondary school teacher interested in improving my teaching practice I wished to learn more about my students' development of scientific concepts and models in teaching them the optics. The choice of optics for my study (Hubber, 2002) was initially a pragmatic one. It allowed me to explore students' understanding of optics over an extended period of time in addition to acting in the dual roles of teacher and researcher. Apart from exploring students' understanding of optics this study also sought to implement teaching and learning strategies within a classroom setting to address any alternative conceptions and mental models that differ from the scientific models. This paper aims to explore what a longitudinal design gave my study in terms of (i) the relationships between the researcher, teacher and students and their effect on the nature of the insights shown, and (ii) the complex nature of learning optics revealed through exploring students' developing and changing understandings of two quite different aspects of optics over three years.

The Study

Secondary school optics in the school at which the research was undertaken deals in Years 7-10 and Year 11 with the scientific concepts involved in geometrical optics. Optics is further studied in Year 12 where the scientific models of light are taught within the topics of physical optics and quantum ideas. A research focus on students' understanding of optical phenomena led me to initially consider the conceptions used by the students to explain aspects of geometrical optics prior to a Year 10 teaching stage. The students' understanding of optics was then explored during two teaching stages, one in Middle School and the other in Year 11. This led to a dual focus on the mental models used by the students to explain the nature of light in Year 12, and the students' understanding of the nature and function of scientific models. The students' mental models, and understanding of the nature and function of scientific models, were then monitored during a third teaching stage in Year 12.

The methodology employed in this research study was that of a longitudinal case study of six Year 10 students' conceptions of optical phenomena over a three-year period. During this time there were three separate teaching stages, each of which adopted a constructivist approach to the teaching and learning of optical phenomena. Multiple methods of data collection were adopted. These included classroom observations, questionnaires, student artifacts, and seven interviews that employed semi-structured questioning. As researcher for this study I also undertook the role of teacher for each of the teaching stages.

The first two years of the study found evidence of:

- Contextualised thinking by some of the students.
- Alternative frameworks in the sense that the students' understandings of a limited number of concepts were consistent across a limited domain.
- Hybridised views that connected aspects of pre-instructional thinking with those scientists' thinking by some of the students.

The students perceived themselves as very much a part of the teaching and learning environment. They discussed their ideas in open forums and assessed the validity of each. The acceptance of any one particular idea over another was a whole class decision. My role as a teacher was encouraging students to discuss and evaluate their ideas with those of the scientific ideas. There was evidence to suggest that many of the constructivist teaching and learning strategies were successful in changing the conceptual understanding the students had about several key concepts in geometrical optics to scientifically more acceptable ideas.

The final year of the study, with its changed focus to the students' mental models of the nature of light, found linkages to the students' conceptual understanding of geometrical optics, and their understanding of the nature and function of consensus models. This gave some insight into the complexities of learning optics.

Relationships between teacher researcher and students in longitudinal design

The longitudinal design with a teacher researcher methodology gave numerous opportunities for data collection in terms of determining the development of the students' understanding of optics both inside and outside the classroom. The ready access to the students both inside and outside the classroom also allowed for multiple methods of data collection. The data collection for the purpose of gaining insight into the students' understanding of optics and the classroom teaching followed a cyclic process. For example, the initial data gave insight into the students' existing knowledge of geometrical optics, which then informed the teaching and learning strategies adopted in the classroom, which gave further insight into the students' understandings, which then informed further teaching.

The roles of teacher and researcher are quite different as they reflect quite different purposes. However, while Baumann & Duffy-Hester (2000) found in their review of teacher research a number of teacher researchers who experienced a tension in undertaking the dual roles of teacher and researcher, I found the dual roles as being compatible. During each interview my role was one of researcher with the sole purpose of probing the student's understandings and viewpoints on a variety of subject matter. There was no intentional purpose to teach the student in terms of indicating the correctness or otherwise of his/her comments with respect to scientific thinking. Exploring the students' viewpoints was a key feature of the interviews and the teaching and learning strategies; a constructivist approach to teaching and learning. From this perspective the dual roles of teacher and researcher adopted in the classroom were to a significant extent compatible with the role of the researcher in the interviews.

A common feature of most lessons in the teaching stages was the discussion of ideas, which turned out to be one of the preferred learning strategies indicated by the students. The following list of comments was made by some of the students as reasons why they preferred discussions:

Beth: [In] discussions you find out what they [other student's views] are like.

Frank: It's more important to have what people think like" when comparing discussions with lectures.

Evan: That's good how we do that sort of thing...you just can't tell people. Like it's easy for them to believe when you find out by yourself.

The role of the teacher during discussions was perceived by the students as allowing different ideas to surface and be discussed without much teacher input. This was reflected in the following students' comments:

Alan: Everyone putting their ideas down on what it is...we just went through them all and we kind of worked our way down to the point where we had one from the whole class.

Frank: [You] allowed discussions to be open, you weren't giving much away.

Christine: After everyone put their ideas forward you just like giving an example to see what would happen.

The application of constructivist teaching and learning approaches allowed me to gain insights into the students' understandings of optics on the one hand and encouraged a change in conceptions on the other hand. Another key feature of the study that assisted both the research and the teaching was the keeping of a research journal of classroom observations, reflections and planning. The regular documentation and personal debriefing of happenings in the classroom had a positive effect on my teaching. The records I was keeping in the research journal informed the teaching and learning. My research journal served two purposes, one purpose was to address my research questions, and the other purpose was to inform me on my classroom teaching.

The emphasis placed on valuing the students' views inside and outside the classroom empowered the students in monitoring their own learning. There was a sense that the students felt the teaching and learning process was a collaborative process involving them and the teacher. This was evident in comments made by the following students in relation to the activities undertaken in the classroom:

Christine: The teacher and students have their ideas and we actually try them out to see if they're right. The students would work through it [the idea] and find out what happens.

Frank: We could continue to work things out by ourselves. That's how it happened.

The close relationships developed between the teacher researcher and the students during the teaching periods that involved geometrical optics allowed significant insight into the students' understanding of concepts and contributed to a successful teaching and learning experiences in the classroom. The relationships also laid the groundwork for exploration into wider issues such as the students' perceptions of the teaching and learning environment in the classroom, and more complex and abstract ideas, such as the students' mental models of the nature of light and their epistemological positions as they relate to the nature and function of scientific models.

The Complex Nature of Learning Optics

The third year of the study took the teaching of optics to a more complex and abstract level with considerations of optical phenomena that require explanations that involve scientific models. The exploration of students' ideas of optical phenomena now required a different focus from one involving conceptual understanding, such as "light travels in straight lines from a torch", to one involving mental and scientific model understanding, such as "light emanates from a torch like very fast particles traveling in straight lines". Another consideration was an exploration of the students' epistemological position as it related to the nature and function of scientific models. That is, do the students understand scientific models as scale models of real objects or do they understand them as representations of ideas or concepts we have of reality?

It was clear from the first two years of the study that the students had developed a strong and long lasting understanding of different concepts of geometrical optics. The longitudinal design then allowed me to reexamine this understanding from the perspective of the scientific models of the nature of light in the interview prior to the third teaching stage and during the teaching stage itself. There was also evidence that at some time during the first two years each student held a mental model of the nature of light whereby rays were perceived as the constituents of light. For example, the following quotes were taken from the students in various artifacts such as concept maps, written and oral responses to questions given in interviews, tests or assignments.

*Alan LIGHT travels in the form of RAYS; RAYS travel to our EYES.
The green filter only lets green rays through the filter.*

*Christine RAYS pass through TRANSPARENT MATERIALS; RAYS reflect in all directions in DIFFUSE REFLECTION; LIGHT is RAYS.
[The candle] gives off the same amount of light, but at day, the sunlight is stronger so it fills in the candle's rays.*

*Evan LIGHT travels in RAYS.
A ray is just a single beam of light.*

*Frank LIGHT makes RAYS; RAYS hit objects and make REFLECTIONS; RAYS don't shine in SHADOWS, RAYS don't hit UMBRA.
[The brightness] ...determines how many rays are being produced. The more rays the brighter the light.*

While the mental model that light actually consists of rays characterises the model as a direct match with reality, a naive realist epistemology (Nadeau & Desautels, 1984), by the third year and before the Year 12 teaching stage three of the students had constructed a more sophisticated epistemology where rays were no longer viewed as real but as representations. The genesis of thinking about rays as real entities of light stemmed from earlier times in language use, drawings of the sun and perceptions of light beams. On the other hand recent classroom work was provided by some of the students as reason

for constructing rays as representations.

Over the period of the Year 12 teaching stage the students changed their mental models of light to involve photons. Some of the main findings from this stage were:

- Hybrid models were constructed which figured photons that contained aspects of both the particle and waves scientific models. That is, the photons had both wave and particle characteristics.
- The hybrid models were perceived by some of the students as actual entities of light whereas other students perceived of them as theoretical entities that metamorphosed as either a particle or wave depending on the phenomenon to be explained.
- There was a large variation in the preferred model used by the students to explain different phenomena of light.
- There was variation in the students' understanding of the nature and function of scientific models.
- Most students constructed a more sophisticated epistemology, closely related to a constructivist view (Grosslight, Unger, Jay & Smith, 1991), as it related to their understanding of the nature and function of scientific models.
- There was some linkage to how students viewed the nature and function of scientific models to how they perceived their hybrid models. For example, the student who viewed his hybrid model as an actual constituent of light retained a naïve realist epistemology position as it related to the nature and function of scientific models. In contrast the students who viewed their hybrid model as a theoretical entity that metamorphosed had developed a constructivist epistemology.

As with the first two teaching stages emphasis was placed in the interviews and teaching stage on the valuing the ideas of the students. In the Year 12 teaching stage the students tested their own mental models against those of the scientific models. The outcome to this was variation by the students in their preference for a particular model to explain various phenomena of light. Over the period of the study I could trace coherence in the students' mental models of the nature of light, and a linkage to their epistemologies.

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