The Teaching of Doppler Effect at Grade 12- Teacher's Content Knowledge

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Abstract

This paper investigates an experienced high school science teacher's content knowledge for teaching Doppler Effect to Grade 12 learners. The topic is new in the physical science National Curriculum Statement and therefore posing some difficulties for teachers when teaching. The aim of this paper is to investigate the content knowledge that the teacher has in order to teach this unfamiliar topic. A research question about what content knowledge for teaching does an experienced teacher possess is answered in this paper. A teacher was interviewed and observed when teaching. A concept map was then constructed based on what was taught. The concept map was then given to different experts for validation of the content before the analysis. Quantitative analysis using the constructs of correctness, connectedness and complexity was then applied and the qualitative analysis was done based on the actual details on the map. In terms of correctness, the findings revealed that the teacher showed a good understanding of Doppler Effect. However, there were some few incorrect links that contributed to the score. There were also only four cross links made by the teacher from his teaching which affected connectedness of the map and hence his conceptual understanding of the topic.

Keywords: *content knowledge, pedagogical content knowledge, Doppler Effect, concept maps*

1. Introduction and Aims

The importance of subject matter knowledge in teaching has been a main concern for education for past three decades. Shulman (1987) considers subject matter knowledge to be the fundamental part of knowledge base for teaching and teachers are regarded as the prime sources of learners' understanding of such knowledge. Shulman also suggests that good teachers should not only know how to get the correct answer but should also have deeper ways of understanding the content. It is also important to highlight that unless a teacher has an adequate knowledge and proper understanding, the content teaching is unlikely to be effective (Grossman, Schoenfeld, & Lee, 2005). It is therefore important that teachers have adequate content knowledge of any topic they are teaching.

Education and training during apartheid era was characterized by the under-development of human potential, generally and that of blacks in particular. The teaching and learning of science was one of the areas that suffered most. Generally, the black science teachers who form the majority of science teachers in this country were under-developed through what was then called Bantu education. Since the inception of democracy, the South African government have introduced different education systems in trying to develop everybody regardless of their race or colour. There have been changes of curriculum from apartheid era education syllabi to Outcome Based Education (OBE), to National Curriculum Statement (NCS) and recently to Curriculum and Assessment Policy Statement (CAPS). Throughout the curriculum changes there has been introduction of new ways of teaching and new content but most teachers in the education system are still those who were trained in Bantu education. Most teachers therefore lack adequate content knowledge.

In a study done on Further Education and Training (FET) physical sciences curriculum, teachers indicated waves as one of the two (the other is mechanics) most difficult knowledge areas for FET physical sciences (Kriek & Basson, 2008). Doppler Effect is mainly based on the knowledge area, waves. Furthermore, Doppler Effect is one of the new topics that were introduced in the new physical science curriculum by the National Curriculum Statement (NCS). It is therefore still a relatively new concept to teachers. However, teachers are expected not only to have a better knowledge of Doppler Effect, but also well-developed content-specific pedagogical knowledge in order to assist their learners to better grasp the concept.

Teaching and learning of science is a problem not only in South Africa, but worldwide. The introduction of new curriculum always comes with its own challenges and the introduction of new science concepts unfamiliar to teachers adds its own challenges. Doppler Effect is one of the new concepts unfamiliar to teachers. Therefore, the interest of this paper is to investigate the content knowledge that teachers have in order to teach this unfamiliar concept. This paper intends to answer the following question:

- What is the experienced teacher's content knowledge for teaching Doppler Effect?

2. Background Literature

2.1 Doppler Effect

Doppler Effect is one of the concepts that were introduced in the new South African curriculum (National Curriculum Statement) recently. This means that teachers do not have experience about teaching the concept to their Grade 12 learners. Doppler Effect is a familiar but abstract science concept taught in secondary physical science and university level (Viennot& Leroy-Bury, 2004). The concept is familiar because learners experience it in their everyday experiences but abstract because the explanation is not always readily available to learners or easily visualised. The difficulty of this topic probably originates from the fact that the waves are invisible and the representations are normally limited to static figures of the phenomenon, which by definition involves movement (Kempston, 2010).

A common misconception of Doppler Effect with learners is that frequency increases as the source moves relatively closer to the observer (Kempston, 2010; Viennot& Leroy-Bury, 2004). This is not the case because the frequency of an approaching object decreases from a value above the emitted frequency, through a value equal to the emitted frequency when the object is closest to the observer, and to values increasingly below the emitted frequency as the object recedes from the observer (Kempston, 2010). What increases is the sound intensity which often leads to this mistake.

While investigating students' understanding after teaching of this topic Viennot and Leroy-Bury (2004) found that about 70% of them correctly predicted that two equal periodic signals emitted by sources of different velocities (with respect to the receiver) would produce signals of different frequencies at the receiver. However, only 50% of them were also able to predict that these frequencies would be equal if the sources had the same velocity but were at different distances from the receiver (Viennot& Leroy-Bury, 2004). This problem is also related to the fact that learners assume Doppler Effect is associated/related to distance. These difficulties and misconceptions found in teaching and learning of the concept are but some of the reasons why the researcher is interested in studying how teachers handle the concept.

This study uses concept map as an analytic tool. Concept Maps are graphic organisation method intended to explore individual knowledge or understanding of topics that are problematic (Kagan, 1990; Novak and Gowin, 1984). Adamczyk and Wilson (1996) argue that, concept maps show a basic understanding of one's content, gaps in knowledge and misconceptions which can be assessed. The teacher's concept map was intended to diagnose how much he knew about Doppler Effect since it is a relatively new topic. Samaras &Freese(2006) argue that concept maps are cognitive tools that allow an individual to demonstrate conceptual connections between concepts.

2.2 Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) is a construct that takes into account the specialized knowledge that teachers possess that enables learners to comprehend what is being taught. Kind (2009) describes PCK as a concept that represents the knowledge used by the teachers in the course of teaching. During teaching it is this knowledge that requires transformation from different domains. The main domain amongst other is the content knowledge (Shulman, 1986). In their studies, Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) and Childs and McNicholl (2007) argue that when teachers have adequate content knowledge for specific topics, their explanations are clear and accurate whilst those with poor content knowledge resort to methods with less interaction. Some research studies have found that even experienced teachers may be less effective when faced with the content that they are less familiar with (Kind, 2009) and this is related to the teacher involved in this study.

2.3 Importance of Teachers content knowledge in teaching

Several research studies have been done on the importance of content knowledge in teaching of science. The studies suggest that teachers' content has influence on classroom practice (Alonzo, 2002; Nehm & Schonfeld, 2007; Heller, Daehler &Shinohara, 2003).Therefore the teaching of Doppler Effect is no exception, that is, teachers who teach this topic should have good understanding of the topic. One of the reasons is that teachers who have low level of content knowledge tend to use the teaching strategies that do not promote learners' conceptual understanding (Cochran & Jones, 1998; Nehm & Schonfeld, 2007; Heller et al., 2003). The studies show that the type of questions that teachers with good subject matter tend to encourage learners' participation through high-level teacher questioning whereas the opposite is the case with teachers with low content knowledge (Cochran & Jones, 1998; Nehm & Schonfeld, 2007). The teachers with low content knowledge also were found to rely mostly on textbooks and always try to avoid open classroom discussions (Cochran & Jones, 1998).

The issue of content knowledge is also discussed by Alonzo (2002) and Sanders, Borko and Lockard (1993). They argue that when teachers have strong content knowledge they tend to use the teaching strategies that challenge learners' misconceptions and help learners to come up with multiple ways of explaining the same phenomenon. The learners are also given permission to be investigative and do more inquiries regarding the topic being taught. This shows that teachers need not to guard against content that is unfamiliar because they are confident about their knowledge.

3. Methodology

This is a qualitative case study focusing on one teacher's teaching of Doppler Effect to Grade 12 learners. This study (forms) is part of a large research done as a requirement for a degree. The teacher who took part in the study is one of four chosen through purposeful sampling. He is one of the teachers believed to be effective with a lot of experience of teaching science.

Mr Liephe is a 52 year old male teacher who has been teaching science for 25 years. He has taught in schools of different socioeconomic class (Private schools, former model C and township schools). However, most of his career (15 years) was spent teaching at four different townships schools. Mr Liephe describes himself as someone who likes developing his learners from 'nothing' to successful individuals. This is one of the reasons he spent most of career time teaching learners of low socioeconomic class.

Data was collected using semi-structured interviews and lesson observations using video for the purpose of triangulation. The interviews were conducted at Mr Liephe's school in his classroom before the first lesson and after the last lesson. Each interview took around twenty minutes and was recorded on the audiotape. The lesson observation of two lessons was done with each taking fifty minutes. Cohen and Manion (1980), suggest triangulation techniques when a more holistic view of educational outcomes is sought. Semi-structured interview was employed due to its flexibility as it enables the researcher to probe for more insight in an idea. Opie (2004), in support, points out that a semi-structured interview allows for depth of feelings to be ascertained by providing opportunities to probe and expand the interviewee's response. Both the audio and video recording were then transcribed and analysed.

4. Data Analysis and Findings

The video tapes of the lessons and the interviews were described and analysed. The researcher went through the video and interview in order to come up with a concept map according to what the teacher was teaching. The words that teacher was using to make the links between the concepts were the ones used on the concept map. The completed concept map was then given to the teacher for discussions with the researcher in order to verify and rectify what was shown on the map. The final map is shown in Appendix B.

The completed concept was then scored using rubric used by Rollnick, Mundalamo and Booth (2008). The rubric used the constructs of correctness, connectedness and complexity to score the concept maps. Below is the outline of the important elements scored in the three constructs as outlined by Rollnick *et al*. (2008);

- *Correctness* – the accuracy of *all* of the links that are written down.
- *Connectedness* **–** an evaluation of the correct cross-links and chunks within the concept map.
- *Complexity* – an evaluation of the structure of the presented knowledge, with no regard to correctness. This score takes into account the number of concepts on the same level, the number of links in the longest chain, and cross linkages. Where there were no cross linkages, this led to a score of 0.

The scoring of the map was validated by a colleague who is an experience physics teacher, a researcher (physics teacher) and also an expert in physics and the use of concept maps. Where there were some differences an agreement was reached regarding the final scoring of the concept map. Shown on the table below are the scores for concept map.

Table 1: Concept map scores

Construct	Score
Correctness	122
Connectedness	6
Complexity	220

Table 1 above shows the scores for correctness, connectedness and complexity. The correctness is calculated by counting the scores for the all the correct links and the cross-links on the concept map divided by the number of nodes, all multiple 100. It is probably important to take a closer look at the number 122. There were 22 links and cross-link in total with 18 nodes. Nodes are concepts that are linked to one or more concepts. Comparison of number of correct links and cross-links shows that not many cross-links were made between the nodes.

Also shown on table 1 is connectedness. As discussed earlier connectedness is the sum of correct chunks and cross-links. A chunk is a group of linked concepts for which the leading concepts has at least two correct successors. The table shows that there were only 6 chunks and cross-links made from the 18 nodes that were on the concept map. The number is the clear indication of how the teacher views a topic as a whole in terms of concepts link to each other holistically.

Lastly there is complexity with a value of 220. Complexity is calculated by looking at the width and the depth of the concept map. It is the product of width, depth and cross-links (see Appendix A).

4.1 Correctness

Although the teacher achieved a high scoring under correctness, there were some incorrect links. Therefore it would have been possible that the teacher could have scored higher. In figure 1 an example of an incorrect link extracted from the concept map is shown;

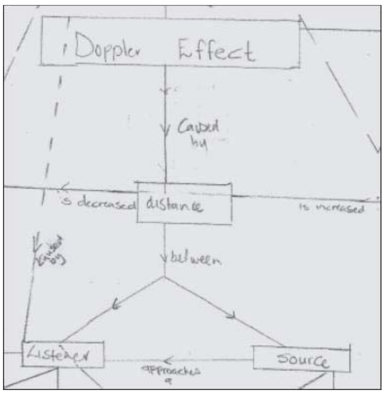

Figure 1: First example of an incorrect link

As it can be seen from figure 1 the teacher shows that Doppler Effect is caused by the distance of Listener and Source, where either the source or the listener is approaching. It is incorrect for the teacher to assume that effect of the distance in this scenario. The teacher does not have a clear understanding that Doppler Effect is caused by the relative movement between the source and the listener. This can happen when either the source or the listener is moving towards or away from the other. The role of distance in apparent change of the frequency as described by the teacher can be taken to be a misconception not a mistake. This is because the teacher also tried to explain how the distance causes the change in pitch as heard by the listen. This is shown on figure 2 below.

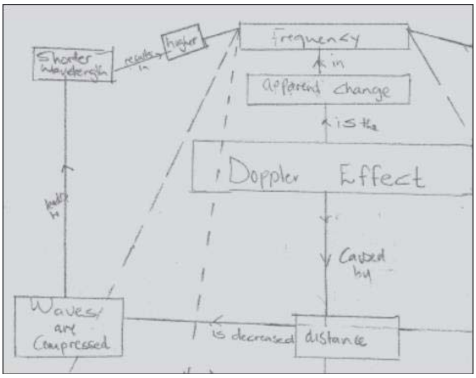

Figure 2: Second example of an incorrect link

It is clear the teacher understands the relationship between wave length and frequency. The links show that shorter wavelength results in high frequency. However, he incorrectly assumes that when the distance between the source and the listener is decreasing that will result in shorter wave length.

In another instant the teacher was trying to emphasise the concept of decreasing and increasing pitch. The extract below (figure 3) shows how the teacher made the links.

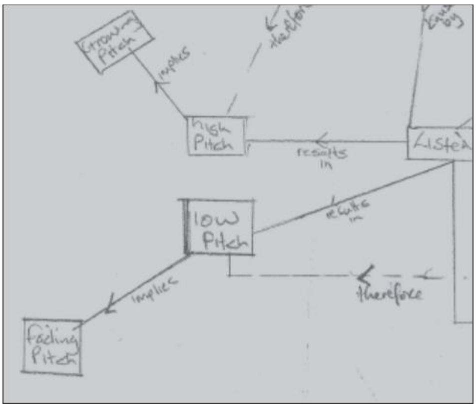

Figure 3: Third example of an incorrect link

In this extract (figure 3) the teacher is using alternative terms for low pitch and high pitch. Low pitch is taken to mean fading pitch while high pitch means growing pitch. It is not clear why the teacher uses the terms interchangeably. Fading or growing could mean that something is decreasing or increasing respectively. However, post-interview with the teacher revealed that fading and growing were here related to the decreasing and increasing sound. This is incorrect because the fading does not necessarily mean that the frequency is getting any lower.

4.2 Connectedness

The concept map had 18 correct links that were identified. 4 of those made the cross-links, while there were only 2 chunks. The teacher makes the cross-link between the frequency, the high pitch, low pitch and the listener. This can be seen on the concept map (Appendix B). The small number of the cross-links out of so many nodes could mean that the teacher does not have a clear understanding of how the concepts are related to each other. This could mean that the teacher does not have a conceptual understanding of the topic as a whole.

4.3 Complexity

The complexity shows the wideness and depth of the concept map. It takes into account all the links, correct and incorrect. Since this paper investigates the content knowledge for teaching Doppler Effect, the assumption is that accuracy of one's content knowledge is crucial. Therefore complexity does not play much role in this paper.

5. Conclusion

It is clear from the analysis of the concept that the teacher has adequate content knowledge about the Doppler Effect. However, there were some few incorrect links that were made between some of the concepts. Literature has shown that one of the misconceptions of the Doppler Effect is that frequency increases as the source moves relatively closer to the observer (Kempston, 2010; Viennot & Leroy-Bury, 2004). This is not the case because the frequency of an approaching object decreases from a value above the emitted frequency, through a value equal to the emitted frequency when the object is closest to the observer, and to values increasingly below the emitted frequency as the object recedes from the observer (Kempston, 2010). What increases is the sound intensity which often leads to this mistake. This was also observed with the experienced teacher participated in this study.

The analysis overall shows that Mr Liephe's content knowledge has few misconceptions therefore it can be regarded as adequate. As indicated earlier under study background, good teacher's content knowledge normally translates into effective teaching strategies. Therefore, it can be inferred that the fact that Mr Liephe's content knowledge was adequate would translate into effective teaching strategies. However, the fact that Mr Liephe's content was found to have some inconsistencies could be taken as an indication that regardless of long teaching experience teachers still need to review their content knowledge every now and then. Therefore all stake holders involved in secondary school education including teachers themselves should encourage teachers training on science content regardless of their experience.

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Appendix A- Rubric for scoring concept maps

Definitions

Node – a word/concept linked to one or more other words/concepts

Link – a direct connection between two nodes on successive levels
Cross-link – a connection between two nodes on either the same level or other levels
Successor – a linked word one level down from a node
Width – the greatest number of concepts at one particular level on the map
Depth – the length of the longest chain on the map
Chunk – a group of linked concepts for which the leading concept has at least two correct successors

Analysis

A. **Correctness**
1. All links are assessed for correctness (cross-links and links)
2. The following rating is provided for each link (Li):
   0 = the link is missing or incorrect
   1 = a link is present, but there are no words or propositions on the link
   2 = the link is represents a basic or superficial idea that while acceptable shows limited or "scientifically thin" knowledge.
   4= the link shows a detailed and sophisticated understanding that is "scientifically rich"
3. All of the scores are added for each link and cross-link, and the final score is divided by the number of nodes. This corrects for the fact that some teachers chose to add extra nodes. The formula is:(L1) + (L2)…)/total number of nodes x 100= Correctness

B. **Connectedness**
1. The correct chunks are determined and the number of correct links (do not include cross links in this count) for each chunk are counted (CNL). A chunk is a group of linked concepts for which the leading concept has at least two *correct* successors. Procedural note: in cases where links can be assigned to more than one node always select the link that creates a chunk if applicable
2. The correct cross-links are determined (CCL).
3. A score for the connectedness is:
   nCNL + nCCL= connectedness

C. **Complexity**
   Procedural note: when redrawing the map in hierarchical form nodes are assigned to a hierarchical level based on their distance from the overarching concept.
1 The width of the concept map is assessed (W). This is the greatest number of concepts at one particular level on the map.
2 The depth of the concept map is assessed (D). This is the length of the longest chain on the map.
3 The numbers of cross-links are counted (CCL).
4 The formula:(W x D) x CCL =complexity

Appendix B