Dialogic Teaching Approach in Teaching Physics vis-à-vis Physics Teachers' Knowledge Domains in Addis Ababa

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This is to certify that the thesis prepared by Deresse Terfa, entitled: *Dialogic Teaching Approach in teaching Physics vis-à-vis Physics Teachers' Knowledge Domains in Addis Ababa* and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy (Physics Education) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

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The purpose of this study was to explore the Ethiopian Second Cycle Primary School (SCPS) Physics teachers' Knowledge Domains (KD)s (Content Knowledge (CK), Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK)) and implementation of Dialogic Teaching (DT). A qualitative method, case study design, and purposive and convenient sampling technique were employed. Data were collected using Classroom Observation, Questionnaire, Content Representation (CoRe), lesson plan, and interview from nine, SCPS physics teachers. The implementation of DT compared using comparative analysis, with respect to training on DT and teachers' KDs. The results have indicated that every teacher has had misconceptions and a lack of procedural knowledge in physics contents, and some teachers' misconceptions were severe. Teachers' understanding of pedagogical knowledge was good, but practically in their class and lesson development, it was naive. Most teachers could not transform their CK to compressible knowledge. Teachers' knowledge of components of PCK was minimal. None of the teachers fully implement dialogic teaching in their class. However, teachers who have training in DT and a higher level of KDs relatively demonstrated DT better than teachers who have no training and have lower KDs, respectively. The researcher recommended that The medium of instruction should be the mother tongue, or teachers should have at least good knowledge of communicative English, professional development training for second cycle primary school teachers and prospective teachers should be well-mentored, supervised, and supported for a long time during teaching practice.

Keywords: Case study, Comparative analysis, Content knowledge, Dialogic teaching, Knowledge domains, pedagogical content Knowledge, Pedagogical knowledge

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Chapter 1: Introduction

The chapter provides a brief background to the study, a statement of the problem, and the rationale for its initiation and statement. It concludes with a description of the research questions of the study.

1.1 Background

One of the objectives of the Education and training policy of Ethiopia (Transitional Government of Ethiopia, 1994) is to offer basic education for all. Ethiopia is in good condition in addressing ”Education For All (EFA)” and in giving attention to Science and Technology by implementing a 70:30 technology and science to social sciences and humanities student admission ratio, which was close to that goal for undergraduates in 2014 (63:37 overall) (Salmi et al., 2017). The percentage of children who had never been to school decreased in Ethiopia (from 67% in 2000 to 28% in 2011) (Barbara et al., 2003). Ethiopia increased its pre-primary Gross Enrolment Ratio (GER) from 2% in 2000 to 34% in 2013/14 (Ministry of Education (MoE), n.d.). The country achieved large increases in primary enrollment rates between 1999 and 2011 with GER increasing from 50% to 106% and its Net Enrollment Rate (NER) from 37% to 87% Barbara et al. (2003). Ethiopian new education and training policy has brought great advantages to the citizens regarding educational equity, primary education in the mother tongue, and democratization of content in education (Ministry of Education (MoE), 2002).

However, the quality of science education and especially physics, is under question. ”Although many effective measures have been taken to maintain quality education, there are critics who claim that, in the name of educational expansion, mediocre education is being sprinkled everywhere like ”holy water” (Tebel)” (Ministry of Education (MoE), 2002, p. 74). A study by Ethiopian National Learning Assessment (ENLA) in four-year time interval for three years (2004, 2008 and 2012) on five subjects (English, Mathematics, Biology, Chemistry, and Physics) at grade 8 have shown students’ mean score in physics is at the bottom than other subjects. Also, Nigussie (2014) indicated that from students who took secondary school National Examination from the year 2002 to 2005, those who were promoted to preparatory school were 31.26%. According to Negassa (2014) in grade 12 national examination, grand mean achievements were 49.51% and in standard test in science for a study group selected from Amhara, Oromia, and Southern Nations, Nationalities, and Peoples' Region (SNNPR) regional states 44.47%. According to Semela (2010), students who join basic science from 2006/7-2008/9 academic year in Ethiopia are low achievers in Ethiopian University Entrance Examination (EUEE). In particular, those who join physics as their carrier are the least achievers. These studies show how science, especially physics education quality, is deteriorating.

Moreover, science education researchers, understanding science education problems, were researching dialogic teaching worldwide. A research project called "Transforming the Pedagogy of STEM Subjects (TPSS)" has conducted similar research in Ethiopia (Alemu, Tadesse, Michael, & Atnafu, 2019). The research has been conducted in two regions (Amhara and South People Nation Nationality Region) and Addis Ababa City Administration. In their final year of teacher education, this study has shown that pre-service physics teachers could score between the highest and lowest Trends in International Mathematics and Science Study (TIMSS) score for grade 8 students internationally.

Factors that affect student achievement are numerous. Some of them are: motivation of the students and teachers (Beal & Stevens, 2007; Broussard & Garrison, 2004; Zhu & Leung, 2011); the mathematical skill of the students (Long & Jiar, 2014); teachers' knowledge (subject matter knowledge, PK, and PCK) (Guerriero, 2012); school facilities (Semaw, 2009); parent's involvement (Bauch, 1994; Epstein, 2010), classroom discourse pattern (Ugwuadu, 2013), etc.

Components of teachers' KD are CK, PK, and PCK (Erduran & Jimenez-Aleixandre, 2008). Guerriero (2012) reviewed each CK and PK has impact on students' achievement and PCK has more impact than CK. Also, a study done by Sampson & Clark

(2008) revealed that teachers' knowledge has a significant positive effect on students' achievement. More specifically, studies done on PCK indicate, PCK has an impact on teachers' teaching performance and students' achievement. Lucenario et al. (2016) has researched four chemistry teachers and their respective chemistry students from two different regular high schools. He found that the PCK- guided lesson study was an effective method to improve teachers' competence and students' achievement in terms of conceptual understanding and problem-solving skills in chemistry. A study in Germany on 1,614 grade 10 students by Keller et al. (2017) shows that physics teachers PCK positively predicted student achievement.

A standard for Ethiopian teachers in second-cycle primary schools was required to have a minimum of Grade 10 education plus a teacher training college (TTC) diploma (Abebe & Woldehanna, 2013; Lassibille & Tan, 2005). Qualification needed for teaching SCPS in Ethiopia is tremendously increased from 28.81% in 2001/2 academic colander (Lassibille & Tan, 2005) to 90% in 2008/9 academic colander (Abebe & Woldehanna, 2013). However, having a diploma from Teacher Training College (TTC) or first degree from university does not warrant the teacher for his knowledge domain. Moreover, some degree graduates did not take pedagogy courses during their studies. Therefore this study will explore teachers KD.

Classroom discourse is a continuum between monologue and dialogue. A monologic teacher is primarily concerned with the transmission of knowledge to pupils and remains firmly in control of the goals of talk. In contrast, dialogic talk is concerned with promoting communication through authentic exchanges. There is a concern for the talk partners' views, and participants made share and build meaning collaboratively. "Sampson & Clark (2008) notions of Dialogic meaning encompass the view that dialogue is not simply between people, but between the frames, people use to categorise categorize" (Lyle, 2008). Initiation-Response-Feedback (IRF) is seen as a monologic style of discourse structure between teacher and pupils (Lyle, 2008). A study done by Ugwuadu (2013) on senior secondary two biology students in Nigeria has shown that democratic/dialogic discourse patterns enhanced students' achievement in biology more than authoritative discourse patterns.

Somebody can talk about what he knows. Our thought can be reflected and well structured through talk. Psychological evidence demonstrates the relationship between language and thought, and the power of spoken language in enabling, supporting, and enhancing children's cognitive development.

To describe what is going on when teachers and pupils work together to build on their own and each others' knowledge and ideas to develop coherent thinking Alexander uses the term "dialogic teaching" (Lyle, 2008). Alexander (2008) argues that dialogic teaching reflects a view that knowledge and understanding come from testing evidence, analyzing ideas, and exploring values (Alexander, 2008, p. 35).

> [Dialogic teaching] explores the learner's thought processes. It treats students' contributions, and especially their answers to the teacher's questions, as stages in an ongoing cognitive quest rather than as terminal points. And it nurtures the student's engagement, confidence, independence, and responsibility.

Writers suggested DT holds the greatest cognitive potential for pupils (Alexander, 2008; Nystrand et al., 1997). Vygotsky and Bruner are the ground for the introduction of dialogic practices. A study done by Hajhosseiny (2012) indicated that DT:

1. Could encourage the students to express ideas and stimulate their courage to dialogue and improve their self-confidence.
2. Motivate the students to have mental challenges and more activities and makes education more dynamic
3. Everyone has a common duty to study the issue and critically dialogue;
4. Provides more possibility for the interaction between student and equal position which leads the student to percept the common rules in discussions, understand the similar rights and respect the right of other students

5. Helps students for more expression of opinions and cooperation and forces them to have more participation and
6. Change the teacher's high and controlling position into a cooperative, interactive, and partner relationship with students.

(Hajhosseiny, 2012, P. 1366)

Motivation and interest development, especially in Science, Technology, Engineering and Mathematics (STEM) subjects, also determine adolescents' willingness to choose STEM-related career paths (PISA, 2007). Interested in learners develop more differentiated domain-specific knowledge (Kiemer et al., 2015), are more focused and have better attention (Ainley et al., 2002), pursue mastery rather than performance goals (Harackiewicz et al., 2008), and receive better grades than uninterested learners (Schiefele et al., 1992). However, interest in the subjects decreases significantly throughout secondary education (Kiemer et al., 2015). One reason for this decrease is the mismatch between students' needs and classroom practices, especially during secondary education (Kiemer et al., 2015).

Verbal teacher-student interaction and peer interactions are a great means of constructing meaning (Mercer, 2010; Kiemer et al., 2015). Interaction quality and language use have important implications for students' learning processes and learning outcomes Kiemer et al. (2015), learning motivation, active engagement, and interest (Sierens et al., 2009).

Attention was given to DT, which is an approach to classroom communication in which teachers and students engaged in the co-construction of knowledge (Alexander, 2008). Alexander's principles of DT have been acknowledged and widely used. These principles of DT are: the talk is collective; the talk is supportive; the talk is reciprocal; the talk is cumulative; the talk is purposeful. Furthermore, DT is also based on distinctive ethical and epistemological stances.

Research shows that DT is effective in promoting the general quality of the classroom talk and students' academic achievement. However, a more monologic approach is still the most common form of classroom communication in schools (Alexander, 2008). In this study, the points of interest were on the SCPS physics teachers' KD and the implementation of DT in their classes.

Good dialogic teaching requires a good teacher's KD and good communication skills in the language of instruction. A teacher should be knowledgeable of her/his CK to ask relevant questions; know the purpose of a question he/she raise and its structure (Alexander, 2003); know how to manage his class; able to prepare a lesson plan for good classroom discussion; conscious of the context, etc. These imply that teachers' knowledge is one factor that affects the implementation of DT.

It was noticed as early as 1983; English as a medium of instruction from grade 7 upwards was a problem for both students and teachers. English is the medium of instruction from grade 7. However, in reality, in many parts of the country, subjects are taught in the vernacular both in grades 7 and 8 (Negash, 2006). Implementing DT in countries where teachers have difficulties in their language and lack of democratic culture is challenging. The medium of instruction for grades 7 and 8 in Addis Ababa is the English language, which is the second language for SCPS teachers. Ethiopian communication culture is not like western countries where democracy is better practiced, and children have freedom of speech. In Ethiopia, children are not free to speak in front of their elders. Therefore, it is challenging to implement DT in Ethiopia.

1.2 Statement of the Problem

Teacher's KD directly or/and indirectly affects student's achievement. Better CK of teachers imply higher student achievement; Better PK imply higher student achievement and PCK has more impact on student achievement than CK. This indicates that CK has direct or/and indirect implication on students' achievement since PCK is either the integration or transformation of CK and PK (Guerriero, 2012; Sampson & Clark, 2008).

Classroom discourse pattern also has an impact on students' understanding and achievement. Dialogue plays a mediational role in helping children reach higher levels of cognitive development (Lyle, 2008). DT treats students' contributions, explores the learner's thought processes, and nurtures the students' confidence, independence, engagement, and responsibility (Alexander, 2006). Dialogic and participatory pedagogy complement and sustain achievement (Deakin Crick et al., 2004).

In Ethiopia, the Second Cycle, primary school student's physics achievement is weak. Grade 8 students' mean score in physics is at the bottom than other subjects. According to Alemu et al. (2019) first, analysis diploma graduates achieved less than grade 7 and 8 students abroad who took the same standard test (Alemu et al., 2019). From observations during second cycle primary school pre-service physics teachers teaching practice, some student teachers were: deficient in their CK of grade 7 and 8 physics; not eliciting students' understanding and misconception; did not encourage students to ask questions.

Even though there are numerous studies about physics teachers KD and their classroom discourse in other countries, to my knowledge in Ethiopia, there is no research conducted on SCPS physics teacher's KD and implementation of DT with respect to grade 7 and 8 physics topics. By exploring the SCPS physics Teacher's CK, PK and PCK related to grade 7 and 8 physics topics and implementation of DT in physics classroom we can better understand the difficulties in SCPS physics education.

1.3 Purpose of the Study

Some studies have been carried out on teachers' KD and implementation of DT in their classes. Literature reveals that studies conducted have focused mainly on investigating the effects of teachers' KD on students' achievement related to different topics. Few studies have explored Topic Specific PCK about the physics topics, and there were studies on the effects of DT on students' understanding.

Although there are studies that explored teachers KDs with respect to topics in physics, whoever SCPS physics teachers' knowledge domain, their implementation of DT in their class and the relation between teachers knowledge and implementation of DT in physics class with respect to second cycle physics topics: Newton's second law of motion and graphical representation of motion were not explored.

SCPS physics teachers are expected to teach basic elementary physics concepts (Ministry of Education (MoE), 2009b). To achieve the objectives of physics education at SCPS, teachers should have the necessary CK of SCPS physics, PCK, and they should transform their knowledge into PCK. Teachers who have knowledge of physics alone could not bring the required students' physics achievement and motivation toward physics and interest in physics. Research findings indicated that DT enables us to engage, motivate, cooperate, support each other, and raise their interest in physics.

The purpose of this qualitative study is to explore Addis Ababa (AA) SCPS physics teachers' KDs (CK, PK, and PCK) and the implementation of DT in their classes, using exploratory case study research design and identify the impact of training teachers on DT and teachers' KD on implementation of DT in teachers' class using qualitative comparative analysis.

1.4 Objectives of the study

The study seeks to explore SCPS physics teachers KD and implementation DT in physics classroom. Therefore the objectives of the study were:

1. to explore the implementation of DT in SCPS physics classroom,
2. to explore SCPS physics teachers' CK associated with grade 7 and 8 physics topics,
3. to explore SCPS physics teachers' PK associated with grade 7 and 8 physics topics,
4. to explore SCPS physics teachers' representation (portray) and the manifestation of their topic-specific PCK related to the teaching of grade 7 and 8 physics topics,
5. to explore how training on DT and teacher's KDs affect SCPS physics teacher implementation of DT.

1.5 Research questions

In line with the objectives of the study, the following questions were addressed:

1. How did DT manifest in the SCPS physics classroom?
2. How was the SCPS physics teachers' CK associated with grade 7 and 8 physics topics?
3. How was the SCPS physics teachers' PK in teaching 'grade 7 and 8 physics topics'?
4. How was the SCPS physics teachers represent (portray) and manifest their topic-specific PCK related to the teaching of 'grade 7 and 8 physics topics'?
5. How did training on DT and teachers' KDs affect SCPS physics teachers' implementation of DT?

1.6 Significance of the Study

This study will be significant in several ways: First, it contributes to Ethiopia's Education and training policy to enhance the quality of Physics Education.

Second, it provides incites into the SCPS physics teachers' KDs and helps physics teachers develop their PCK through CoRe. As a result, it enhances students understanding of the subject matter and enables students to build a democratic attitude in their class and their society.

Third, it aware curriculum development and evaluation department that SCPS textbooks revisited.

Fourth, it provides incites into implementation DT in SCPS physics class.

Fifth, it contributes to the literature as no studies have been identified that how training on DT affects teachers KD and how KD affects implementation of DT in physics class.

1.7 Operational Definition of Terms

1. **Content knowledge:** is the knowledge that a physics teacher holds and tends to teach his students.
2. **Pedagogical knowledge:** is knowledge about the practices and processes or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims.

3. **Pedagogical content knowledge:** Integrated/transformed physics content, pedagogical and contextual knowledge of a teacher in an easily comprehendible way to learner.
4. **Knowledge Domains:** Diverse Knowledge and skills that teachers need when planning and teaching.
5. **Initiation-response-feedback:** is a traditional pattern of discussion between teacher and students, in which students' ideas are not reflected, and students' questions are limited.
6. **Content Representation (CoRe):** is a tool developed by Loughran et al. (2004) to capture and portray PCK.
7. **Dialogic teaching:** is using talk most effectively for carrying out teaching and learning.

1.8 Structure of the study

The study comprises five chapters. The first chapter is an introduction to the study. It provided the study's background, the statement of the problem, the purpose of the study, the research questions, and the problems and the significance of the study. Finally, The researcher explained how the dissertation is structured. The second chapter provided the philosophical and theoretical setup of the study and review on constructivist learning theory, teachers' KDs (CK, PK, and PCK), their development, and dialogic teaching principles. Furthermore, the chapter provided a conceptual framework for the study.

The third chapter provided the research design and research methods chosen to answer the research questions. Chapter four attempted to address the six research questions by examining how the teachers portrayed and demonstrate their KDs (CK, PK, and PCK) and demonstrated DT in their classes. The chapter also examined teachers' CoRe, lesson plan, response to questionnaire, and classes. The fifth chapter concluded the study based on discussion from chapter 4.

Chapter 2: Literature Review

2.1 Introduction

Teachers' knowledge domains and classroom discourse are the determining factors in effective teaching and learning. This study explored the SCPS physics teachers' KD and DT in their classes. This chapter has reviewed the theoretical framework of the study, different models of domains of teachers' knowledge (CK, PK, and PCK), Developments of teachers' Knowledge and conceptions and principles of DT. Models that were adapted and developed were described. At the end of the chapter, a summary of the literature review and conceptual framework are given.

2.2 Theoretical Framework of the Study

This study is grounded in radical constructivism and social constructivism framework. Constructivists view knowledge as nonobjective, internally constructed, temporary, developmental, and socially and culturally mediated (Kim, 2001). Individuals are assumed to construct their meanings and understandings, and this process is believed to involve an interplay between existing knowledge and beliefs and new knowledge and experiences (Richardson, 2003). Some theorists of Constructivism are Vygotsky, Lave & Wenger, Piaget, Bransford, Hasselbring, Grabinger, Spiro, and colleagues (Walshaw & Anthony, 2008).

Jean Piaget (1896-1980) stated that learning is a developmental cognitive process, that students create knowledge rather than receive knowledge from the teacher. He argued that students construct knowledge based on their experiences (Shahram, 2002). Lev Vygotsky (1896-1934) extended Piaget's developmental theory to include the notion of social-cultural cognition. All learning occurs in a cultural context and involves social interactions. Lev Vygotsky emphasized the role that culture and language play in developing students' thinking and how teachers and peers help learners develop new ideas and skills. Vygotsky suggested the concept of the zone of proximal development (ZPD)(Shahram, 2002).

There are eighteen different constructivism forms in terms of methodological, radical, didactic, and dialectical considerations (Mathews, 2000). Scholars and theorists place all constructivism forms in three distinct categories: sociological, psychological, and radical constructivisms. They share that knowledge or meaning is not discovered but constructed by the human mind (Richardson, 2003).

Radical constructivism, introduced by Glasersfeld (1995), assumes that external reality cannot be known and that the knowing subject constructs all knowledge, ranging from everyday observations to scientific knowledge; knowing thus reflects the observer's perspective (Molebash, 2002; Terhart, 2003). Knowledge of a teacher, mainly PCK, develops through experience, and teachers' Topic Specific Pedagogical Content Knowledge (TSPCK) can vary from teacher to teacher. For the same topic, teachers may develop their TSPCK differently; this indicates that teachers' knowledge bases on radical constructivism.

The importance of culture and context has emphasized constructivism, understanding what occurs in society and constructing knowledge (Derry, 1999; McMahon, 1997); this is associated with Vygotsky and Bruner's developmental theories and Bandura's social cognitive theory (Kim, 2001).

Social constructivists consider that reality is constructed; Members of society together invent the properties of the world (Kukla, 2000); reality cannot be discovered; knowledge is a human product, and is socially and culturally constructed (Prawat & Floden, 1994; Gredler, 1997). Individuals create meaning through their interactions with the environment they live in and with each other. Social constructivists view learning as a social process. It does not occur only within an individual, nor is it a passive development of behaviors shaped by external forces (McMahon, 1997). When individuals are engaged in social activities, meaningful learning occurs since DT features are collective, reciprocal, supportive, communicative, and purposeful, which involve teacher-student and student-student interaction. Therefore, DT bases on social constructivism.

In constructivists' view, teachers should no more be suppliers of science knowledge, and classroom managers and students should no more be passive receivers of science knowledge supplied by teachers(Fosnot & Perry, 1996). These make students creative, critical thinkers, participants of their issue rather than passive and accepting ready-made concepts. Constructivist views also emphasize generative learning, questioning, and inquiry strategies Slavin (2019). These help students experience argumentation and dialogue in the scientific community in their future careers. Students share their views and learn from each other.

When a teacher enters a class, he/she thinks of what to teach and how to teach. A science teacher should be well-equipped with the content knowledge and the pedagogy of science and transform them for a particular topic. Moreover, The Ethiopian education and training policy recommends a student-centered teaching approach based on constructivist learning theory. Therefore, the constructivist theory (Radial and social constructivism) underpin this study.

2.3 Teachers' Knowledge Domains (KD)

Research claims that teachers' intellectual resources affect students' achievement (Ball, 1989). A study by Tchoshanov et al. (2008) supports the same claim and shows that teachers' knowledge and student achievement parallel each other. According to L. S. Shulman (1986), teachers' knowledge is classified into Subject matter content Knowledge, Pedagogical Content Knowledge, and Curriculum knowledge. Subject matter content knowledge addresses the quantity and organization of knowledge per se in the mind of the teacher (L. S. Shulman, 1986).

PCK goes beyond knowledge of subject matter (L. S. Shulman, 1986). According to National Science Education Standards," PCK is distinctive understandings and abilities that integrate teacher knowledge of science content, curriculum, learning, teaching, and students, allowing science teachers to tailor learning situations to the needs of individuals and groups (National Research Council and others, 1996)." PCK includes topics, the most useful forms of representation, the most powerful analogies, illustrations, examples, explanations, and demonstration (L. S. Shulman, 1986).

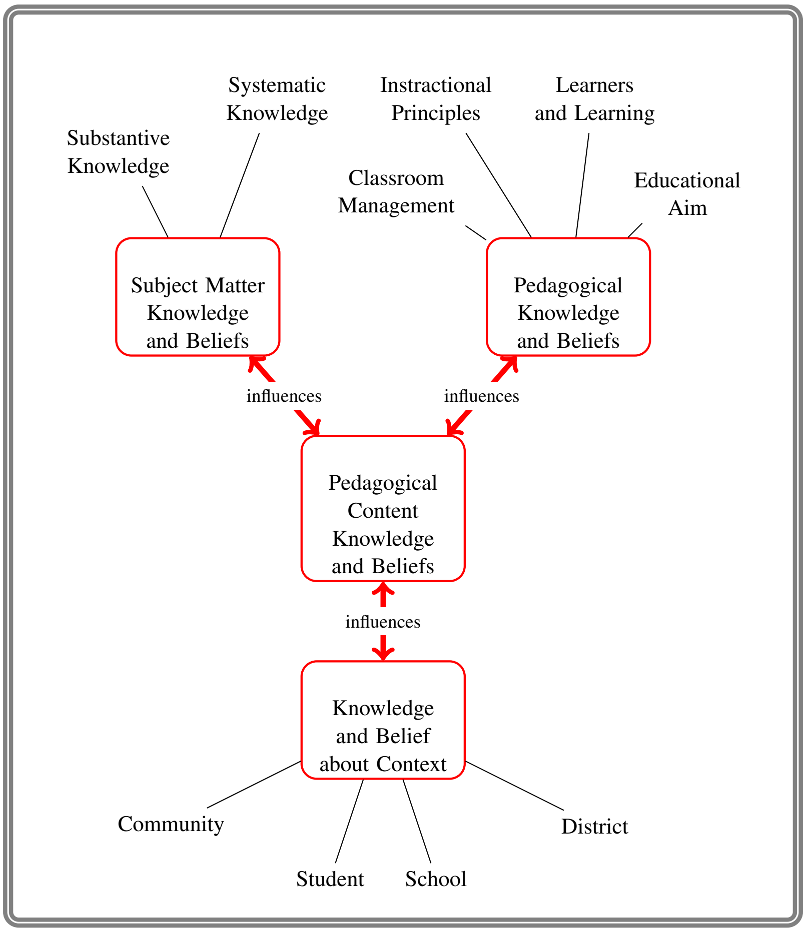


Figure 2.1: Relationships among the teachers' KDs (Grossman, 1990).

Following L. S. Shulman (1986)'s work, literature addressed various components of teachers' knowledge and classified into: Subject matter knowledge Content Knowledge, general pedagogical knowledge, and Pedagogical Content Knowledge (Erduran & Jimenez-Aleixandre, 2008). Grossman (1990) has related teachers' knowledge domains, as shown in Figure 2.1. The box in the figure indicates the significant domains of knowledge for teaching. In the next subsections, these teachers' knowledge domains are seen.

2.4 Content Knowledge (CK)

CK is a knowledge held by a subject teacher, which he/she intended to teach his/her students. It is knowledge about the actual subject matter that is to be learned or taught. Teachers must have a clear understanding of the topics of the subject they teach (L. S. Shulman, 1986). Teachers must also understand the nature of knowledge and inquiry in different fields. Content knowledge is the knowledge held by a content expert (Gess-Newsome & Lederman, 2001).

Experience and CK of a teacher can affect his/her PCK. Research is done by Clermont et al. (1994) has indicated that novice teachers' declarative knowledge is limited to applying CK to teaching. In contrast, experienced teachers are more accurate in their explanations about and selecting appropriate demonstrations for teaching specific concepts, and are more confident in their CK (Cess-Newsome, 1999).

Teachers who were teaching topics within their area of expertise had more advanced knowledge of related concepts, disciplinary principles, and specific methods of connecting the target concept to other concepts. For a teacher, teaching outside his/her content area is difficult. Knowledgeable teachers were more likely to ask higher-level questions, move beyond the textbook, require the synthesis of many related ideas, identify student misconceptions, and act on opportunities to enhance the content based on student comments. In contrast, unknowledgeable teachers rely on recall questions related to the content in the text (Cess-Newsome, 1999).

Borko & Livingston (1989) found that when experienced teachers teach outside their area of expertise, they fall back to a behaviorist. They spend more time planning and practicing classroom lessons, and are limited in the sense of sequence, topic importance, content structure, students' background knowledge.

Despite their bachelor's degree and high levels of confidence in their CK, most preservice teachers have no understanding of the content they teach in a conceptually rich or comprehendible manner Brookhart & Freeman (1992). Instead, most novice teachers' CK is fragmented, poorly organized, and compartmentalized, making it difficult to access this knowledge when teaching efficiently. As a result, many novice teachers are forced to teach the algorithms and facts (Talbert et al., 1993).

Many orientations view teachers as knowledge dispensers and learning as remembering. These views tend to give attention to more content-specific goals and dominant teacher decision making. When teachers have weak initial orientations, they appear to adopt the orientations in embedded texts, curriculum guides, or university course work

(Cess-Newsome, 1999). CK of a teacher plays a great role in the classroom experience. Without a substantial CK base, the adoption of constructivist teaching methods may be unrealistic (Mosenthal & Ball, 1992; Smith & Neale, 1989).

In general, CK is a prerequisite for a teacher to teach. Somebody can invite something to others if he/she has. The way he/she delivers his invitation is based on the inviter's invite. So a teacher has to know his/her subject area to teach. Otherwise, it is similar to inviting somebody without any invite in hand. On the contrary, even though there are numerous studies on students' physics misconceptions, but I could not find a study that shows physics teachers' misconceptions, especially on Newton's law of motion and graphical representation of motion. CK has two components: conceptual and procedural knowledge (Groth & Bergner, 2006). The two components are discussed in subsection 2.4.1.

2.4.1 Conceptual vs. Procedural Knowledge

Different scholars define conceptual knowledge as follows:

- "Explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain," (Rittle-Johnson & Alibali, 1999)
- "Ideas, connections, relationships, or having a 'sense' of something." Barr et al. (2003)
- "Learning that involves understanding and interpreting concepts and the relations between concepts." (Arslan, 2010)
- "To know why something happens in a particular way." (Hiebert & Lefevre, 1986)

Similarly, the scholars defined Procedural Knowledge as follows:

- "Action sequences for solving problems," (Rittle-Johnson & Alibali, 1999)
- "Like a toolbox, it includes facts, skills, procedures, algorithms or methods." Barr et al. (2003)
- "Learning that involves only memorizing operations with no understanding of the underlying meanings." (Arslan, 2010)

- ”To know how something happens in a particular way.” (Hiebert & Lefevre, 1986)

Arslan (2010) set comparison questions measuring conceptual and procedural knowledge, as shown in Table 2.1. There is a relation between procedural and declarative forms of knowledge, and one can be derived from the other Harackiewicz et al. (2008). Anderson (2015) argue that ”knowledge starts with declarative actions, the conscious and control; Moreover, this control paves the way for procedural processes. On the other hand, procedural knowledge has significant roles in structuring concepts and obtaining declarative knowledge” (Lawson, 1991; Lawson et al., 2000).

Table 2.1: Questions measuring conceptual and procedural knowledge

Question measuring procedural knowledge has:	Question measuring conceptual knowledge has:
(i) it consists of an application of existing knowledge (ii) the knowledge required by the question was taught previously (iii) the task given in the question has already been discussed in the class (iv) it involves making calculations step by step just as was taught (v) it requires cognitive skills at the knowledge level of Bloom's taxonomy (theorems, definitions, etc.) (vi) it involves the only mechanical application of the knowledge taught. While answering such questions, the individual generally uses memorized knowledge without needing to understand the concept thoroughly. Without applying existing knowledge in different learning environments	(i) it requires understanding newly encountered ideas (ii) the knowledge required by the question was not previously taught (iii) the task given in the question has not been discussed in the class (iv) it provides students with the opportunity to respond flexibly (v) it requires cognitive skills at the higher levels of Bloom's taxonomy (vi), it involves perceiving the concepts deeply and associating different concepts with each other. While answering such questions, students form associations with their existing knowledge, express their knowledge using different representations (oral, graphical, etc.), demonstrate the ability to shift between these representations, and apply their existing knowledge in different situations even if it is in another domain of mathematics

(Arslan, 2010)

2.4.2 Conceptions of Motion and Force

Aristotle's thought needed to explain why motion occurs and change. Aristotle categorized motion into:

- **Natural motion**, came from the tendency of objects to go to their "natural" place, on the ground, and come to rest.
- **Voluntary motion** type of motion exhibited by animals, which moved because they chose to.
- **Forced motion**, occurred when an object was acted on by some other object that made it move (Crowell, 2001).

Aristotle's work can be summarized as $\vec{F} = m\vec{v}$. In other words, if there is no force on an object, the object has no velocity (Lark, 2007). Aristotelian sees force as an intrinsic property of objects, where objects can create, destroy, or alter their internal force to get to rest in the objects' domain of choice (Crowell, 2001). This internal force was called impetus. Interactions between two objects (mainly animals and humans) is called violent motion; this means the only living thing can exert force (Crowell, 2001).

Crowell (2003) notes: "Although this basic theory appears to be a reasonable outcome of experience with real-world motion, it is strikingly inconsistent with the fundamental principles of classical physics. In fact, the naïve theory is remarkably similar to a pre-Newtonian physical theory popular in the 14^{th} through 16^{th} centuries."

Newton defined his three laws of motion, which are completely different from Aristotle's long-standing view, in his book Philosophiae Naturalis Principia Mathematica, published in 1679 Lark (2007). The first law is summarized as objects keep moving or remain at rest unless an external force is applied on it, which contradicts Aristotle's view that forces cause motion and objects tend towards rest. Newton's second law ($\vec{F} = m\vec{a}$), differs mathematically as well as conceptually from the previous $\vec{F} = m\vec{v}$. The motion of a body is not maintained by force but changed by the application of a force. Newton's third law states that there is equal and opposite reaction force for every action, in contrast to Aristotle's view, where force is mostly an internal entity. The goal of physics classes is to shift physics students from the more intuitive Aristotelian view to the more scientifically accepted Newtonian view Lark (2007).

Hestenes & Wells (1992) classified the Newtonian force concept into kinematics, First law, second law, superposition principle, and kinds of force; also, the two main kinds (types) of force (contact and non-contact forces) classified into solid contact, fluid contact, and gravitation. Force Concept Inventory (FCI) data has detected misconceptions in motion and force. It confirms the similarity of misconceptions with other educational researchers. Most misconceptions identified are similar to the Aristotelian conception of force. Misconceptions probed by Hestenes & Wells (1992) were classified as kinematics, impetus, Active force, action/reaction pairs, Concatenation of Influences, and other influences on motion (Hestenes & Wells, 1992).

Studies show that students at the college and high school level (Thornton & Sokoloff, 1998; Clement, 1982; Brown & Clement, 1989; Thijs, 1992), have misconceptions consistent with Aristotelian mechanics. A study by Brown (1989) indicated that high school students enter physics classes with preconceptions in the area of Newton's Third Law, which results from students' general naive view of force as a property of single objects. (Brown, 1989).

Even though at different grade levels students' CK were studied, there are no studies on in-service second cycle primary school teachers, which explore primary physics teachers' CK, especially on Newton's law of motion and graphical representation of motion. Therefore, this issue was one primary aim of this study.

2.5 Pedagogical Knowledge (PK)

"PK is deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims" (Mishra & Koehler, 2006). It is involved in student learning, lesson plan development and implementation, classroom management, and student assessment. It includes knowledge about methods used in the classroom, the aimed audience's nature, and strategies for assessing student understanding. "A teacher with a deep [PK] understanding of how students construct knowledge, acquire skills and develop habits of mind and positive dispositions toward learning. As such, [PK] requires an understanding of cognitive, social, and developmental theories of learning and how they apply to students in their classroom" (Mishra & Koehler, 2006).

L. S. Shulman (1986)'s definition of pedagogical knowledge was limited to classroom management and organization. Recent conception integrates components of the teaching-learning process. According to Voss & Kunter (2013) model, "general pedagogical/psychological knowledge" comprises of five sub-dimensions:

- **knowledge of classroom management** (maximizing the quantity of instructional time by having an awareness of activities in all parts of the classroom, teaching at a steady pace to maintain momentum, handling classroom events at the same time, maintaining clear direction in lessons and keeping the students alert)
- **knowledge of teaching methods** (making productive use of instructional time by having a command of various teaching methods and knowing when and how to apply each method)
- **knowledge of classroom assessment** (knowledge of different forms and purposes of formative and summative classroom assessments and knowledge of how different frames of reference [e.g., social, individual, criterion-based] impact students' motivation)
- **knowledge of learning processes** (supporting and fostering individual learning progress by having knowledge of various cognitive and motivational learning processes)
- **knowledge of individual student characteristics** (meeting individual student needs by having knowledge of the sources of student cognitive, motivational, and emotional heterogeneity) (Guerriero, 2017, p. 106).

In this model, in addition to pedagogical components–knowledge of classroom management, teaching methods and classroom assessment, Psychological components–knowledge of learning processes and individual student characteristics are included. Also, Konig et al. (2011) proposed a general pedagogical knowledge model, which consisted of four dimensions (Guerriero, 2017): structure, motivation, and classroom management, adaptivity, and assessment. This study explored the SCPS physics teachers' general pedagogical knowledge using Voss & Kunter model. From the model, only the three sub-dimensions: knowledge of classroom management, knowledge of teaching methods, and knowledge of classroom assessment were explored.

2.5.1 Classroom Management

Some teachers may believe that if students are quiet and listen to them only, the classroom is well managed. However, a productive learning environment can often be noisy because learning is not a passive activity. Learning requires talking, sharing, discovering, experimenting, and questioning, all of which can create noise.

Research shows that effective and less effective classroom managers differ not in the strategies they use to interfere with disruptions but in the use of preventive strategies to avoid disruptions in the first place (Kunter et al., 2013). Goals of Classroom Management to develop a conducive academic and social-emotional learning environment (Garrett, 2014). Classroom management consists of:

1. **Physical design of the classroom** –The physical design lies in how the classroom is laid out, where the students' and teacher's desks are, where learning centers and materials are located, and so on. ,
2. **Rules and routines** –Teachers establish class rules and routines to keep the class activities running smoothly with as little disruption and loss of time as possible. ,
3. **Relationships** –Effective classroom managers develop caring, supportive relationships with students and parents and promote supportive relations among students. ,
4. **Engaging and motivating instruction** –Effective managers develop instruction that engages learners, and they carefully plan their instruction so that each learning activity is well organized and runs smoothly. and
5. **Discipline** –Discipline is concerned with a teacher's actions focused on both preventing and responding to students' misbehavior. It is not only a means of punishment, nor the actions that teachers take after misbehavior occurs. Discipline

also includes teacher actions that prevent misbehavior (Garrett, 2014, P. 3).

All components of classroom management (physical design, rules and routines, relationships, and engaging instruction) are aimed at preventing misbehavior rather than responding to it, except the fifth. The fifth component, discipline, includes both actions designed to prevent misbehavior and actions that respond to it (Garrett, 2014).

2.5.2 Teaching Methods

A teaching method is characterized by a set of principles, procedures, or strategies to be implemented by teachers to achieve desired learning in students (Marzano & Gaddy, 2005). A large number of educational psychology methods are classified as either teacher-centered (direct teaching) or student-centered (Kunter et al., 2013). The teacher-centered approach is based on instructivist or direct-teaching principles, and the student-centered approach is based on constructivist principles.

Both constructive and instructive approaches have their own merits in the total context of teaching and learning, but may not be equally effective for achieving particular goals in education (Scruggs & Mastropieri, 2007). Therefore, the most appropriate teaching methods should be chosen for specific purposes (Kuhn, 2007).

Direct teaching methods are the most effective for teaching the early stages of foundation skills such as literacy and numeracy (Westwood, 2008) and are also appropriate in many other contexts and can be implemented with huge groups. Direct teaching takes many forms, ranging from the typical chalk-and-talk or PowerPoint lecture – where students are mainly passive recipients of information –through to highly structured but interactive classroom sessions (Westwood, 2008).

Teaching methods that are described as 'student-centered' are aligned with the constructivist theory of learning. Some examples of student-centered approaches are activity-based learning, guided discovery, inquiry approach, problem-based learning, project-based learning, and situated learning (Westwood, 2008).

2.5.3 Classroom assessment

Classroom assessment is the process of collecting, synthesizing, and interpreting information to aid in classroom decision making (Airasian, 2001). In a class, a teacher wants to know about students' understanding, background, and learning style. Therefore, to make decisions about instruction, student learning, classroom management, and planning, the teacher gathers and uses information. Teachers decide about the success of their instruction, their students, and the classroom climate.

An assessment has many purposes. These purposes include establishing a classroom that supports learning, planning and conducting instruction, placing students, providing feedback, diagnosing student problems and disabilities, and summarizing and grading academic learning and progress (Airasian, 2001). The test is one of the tools for gathering assessment information. Hence, classroom assessment includes much more than tests and quizzes.

Classroom assessment takes place for three major domains. The cognitive domain comprises intellectual activities such as memorizing, interpreting, applying knowledge, solving problems, and critical thinking. The affective domain involves feelings, attitudes, values, interests, and emotions. The psychomotor domain includes physical activities and actions in which students must manipulate objects such as a pen, a keyboard, or a zipper (Airasian, 2001).

"Assessment information can be categorized into three general phases of classroom assessment: Early, Instructional, and summative" [P. 8]. An early assessment provides a quick perception and practical knowledge of students' characteristics for the teacher; Instructional assessments plan instructional activities and monitor the progress of instruction, and Summative assessments carry out the bureaucratic aspects of teaching, such as grading, grouping, and placing (Airasian, 2001).

Student products, observation techniques, and oral questioning techniques are the three primary methods of gathering information in the classroom. Any activity that a teacher asks a student to do is a student's product, for example, written assignments, homework, worksheets, essays, lab reports, science projects, artwork, portfolios, tests, and quizzes.

Observation involves a teacher ”listening to or watching students’ activity or response in a given situation” [p. 12]. All questions a teacher raises in the classroom to collect information from students during his/her classroom are called Oral questions. Questioning can be used to brainstorm new concepts, review a previous topic, find out how the lesson is being understood, and engage a student (Airasian, 2001).

In general, a teacher should know how to deliver his/her content knowledge, how students are initiated and engaged in constructing their knowledge, and how he/she makes his/her knowledge visible to his/her students. To do so, a teacher should have adequate PK. We can consider an inviter who invites others as an analogy. When somebody invites others, he/she has to know how to deliver his/her invitation. The inviter should know where to invite, the time of invitation, the material needed for an invitation, the invitees’ culture, and how to entertain his invitees. Otherwise, the invitation will not be successful only by having an invite. Since teaching is to make the subject matter understandable and make students able to construct their knowledge, a teacher should create a conducive environment, know his students’ interests and styles of learning, and choose more appropriate methods of teaching for a topic he is going to teach.

2.6 Pedagogical Content Knowledge (PCK)

A teacher should have a deep understanding of his/her subject area. Also, he/she must be able to enhance the understanding of the subject or concepts for students. L. S. Shulman (1986) pointed out a missing paradigm regarding learning environments with respect to teachers and called this paradigm a PCK. According to L. S. Shulman (1986) pedagogical content knowledge

> . . . for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations in a word, the

> ways of representing and formulating the subject that make it comprehensible to others . . . [PCK] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (L. S. Shulman, 1986, p. 9).

PCK is a unique knowledge of a teacher to represent a particular topic for instruction and bound with "diverse interests and abilities of learners" (L. Shulman, 1987). PCK is a form of knowledge that is concerned with making science teachers, teachers rather than making scientists (Gudmundsdottir, 1987; Cochran, 1997). What makes science teachers different from scientists is not necessarily the quantity or the quality of CK, instead of how CK is organized and used in instruction. PCK was mentioned as a new type of CK comprises of other knowledge domains such as 'Knowledge of the learner,' 'knowledge of the curriculum,' 'knowledge of the context,' and 'knowledge of pedagogy' (Ozgen, 2012).

Being qualified in his/her subject area does not warrant a teacher for comprehendible teaching. "Although many successful science teachers are academically well-qualified in their specialist subjects, possession of a good Bachelor's degree in a science subject, or simply enhancing subject knowledge where this is weak, does not offer de facto guarantees that someone will teach a specific subject effectively" (Kind, 2009, p. 171).

Researchers have reached a consensus partially related to PCK.

1. PCK includes knowledge of representations and knowledge of students.
2. CK has a central importance for PCK . That is, CK is a prerequisite for well-structured PCK.
3. Beliefs of teachers affect their decisions in the classroom, and hence their PCK structures.
4. PCK develops with classroom practice.
5. PCK can be used as an 'organizer' for teacher education, professional

development, and certification programs (Ozgen, 2012, p. 14).

Science teachers' PCK is deeply personal, highly contextualized, and influenced by teaching interaction and experience (Jong et al., 2005; Van Dijk & Kattmann, 2007). Mulholland & Wallace (2005) suggested that science teachers' PCK requires the longitudinal development of experience as they develop from novices into experienced teachers. PCK is a form of teachers' practical knowledge Van Driel et al. (1998); this implies that beginning teachers can hardly learn PCK from a textbook, or a short course only (Jong et al., 2005).

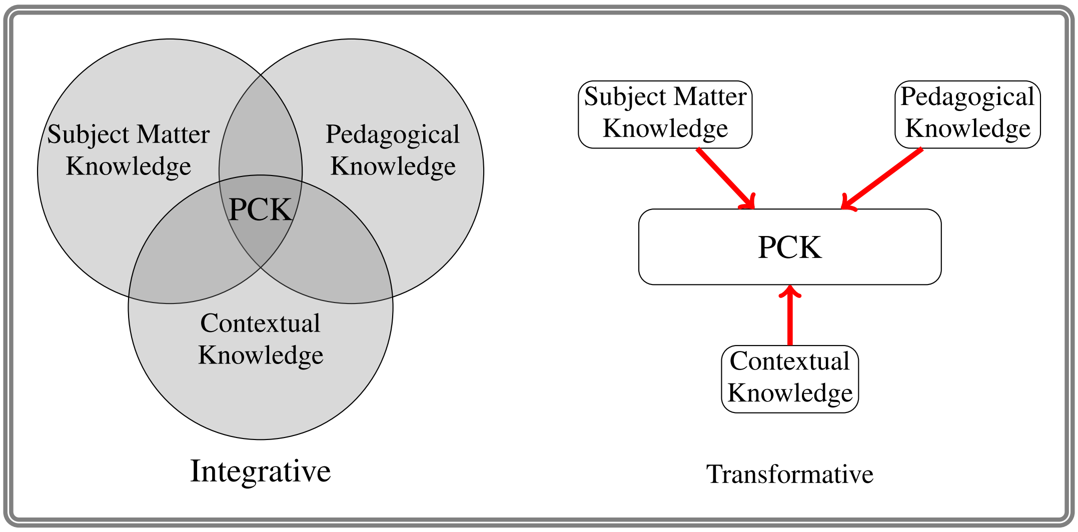


Figure 2.2: Representations of Models (Gess-Newsome, 1999).

Figure 2.2 shows Gess-Newsome (1999)'s the transformative and integrative models for PCK. In the integrative model, knowledge domains: subject matter, pedagogy, and context tend to exist as separate entities. In the transformative model of PCK is recognized as a synthesized knowledge base for teaching. A beginning teacher tends to rely more heavily on one domain of knowledge rather than drawing simultaneously from all domains (Grossman, 1990). The transformative model represents more the PCK of experienced teachers, while the integrative model portrays the PCK of beginning teachers (Lee & Luft, 2008).

Veal & Makinster (1999) suggested that there were three different types of PCK: general, domain-specific, and topic-specific. General PCK is related to science as a subject; domain-specific PCK is connected to different domains within science, such as chemistry, biology, Earth science, and physics; and topic-specific PCK is relevant to a list of concepts, terms, and topics in each domain (Lee & Luft, 2008).

Therefore, PCK involves having a general PK, choosing the appropriate one, and implementing specific content knowledge in certain circumstances. As an analogy, any invitation is successful, not only by having an invite and/or materials. The inviter should have the skill of choosing appropriate materials for the invite depending on the existing condition. For example, ”kurti” (raw meat) and ”kitfo” are the same except ”kitifo” is ground. ”Kurti” requires a knife while ”kitifo” requires a spoon to feed.

2.6.1 Components of PCK

Researchers try to figure out ”What are the components of PCK” (Jing-Jing, 2014). Schulman (1986) conception of PCK includes three components: knowledge of topics taught in one’s subject area, knowledge of representation of those ideas, and knowledge of students’ understanding of the topics. This conception expanded and specified by L. Shulman (1987) to the three components of PCK: knowledge of the central topics, concepts, and areas of the subject matter that can be and are taught to students and knowledge of analogies, similes, examples, and metaphors; knowledge of the different ways topics can be taught, and the pros and cons of each approach; and knowledge of students’ preconceptions or misconceptions about the topics they learn, and knowledge of the topics students find interesting, difficult or easy to learn (L. Shulman, 1987; Jing-Jing, 2014). These components are shown in Table 2.2.

Table 2.2: Shulman’s conception of components of PCK

PEDAGOGICAL CONTENT KNOWLEDGE		
Knowledge of Students Understanding	Curricular Knowledge	Knowledge of Instructional Strategies

Tamir (1988) extended L. Shulman (1987)’s conception of PCK by including knowledge of evaluation. Tamir (1988) conception of PCK emphasizes on both declarative and procedural nature of PCK (Jing-Jing, 2014). Grossman (1990)’s conception of PCK includes four components: conception of teaching purposes, knowledge of students, curricular knowledge, and knowledge of instructional strategies. Compared with L. Shulman's conception, knowledge of conceptions of purposes for teaching subject matter is added into Grossman's conception of PCK components. These components are demonstrated in Table 2.3.

Table 2.3: Grossman's conception of components of PCK

PEDAGOGICAL CONTENT KNOWLEDGE			
Conceptions of Purpose for Teaching Subject Matter	Knowledge of Students Understanding	Curricular Knowledge	Knowledge of Instructional Strategies

Marks (1990) conception of PCK components is based on the findings of the study he conducted. According to Marks (1990)'s finding, PCK comprises four major areas: subject matter, students' understanding; media for instruction; and instructional processes for the subject matter (Jing-Jing, 2014). Table 2.4 shows Marks's four components of PCK.

Table 2.4: Marks' conception of components of PCK

PEDAGOGICAL CONTENT KNOWLEDGE			
Subject matter	Students' understanding	Media for instruction	Instructional processes

Cochran et al. (1993) modified L. Shulman's PCK in accordance with constructivist perspective and they preferred to call PCK as Pedagogical Content Knowing (PCKg). PCKg is developing in time via teachers' implementations in the classroom context and has four components: The Knowledge of pedagogy, The knowledge of subject matter content, The knowledge of students, and The knowledge of environmental contexts.

In this model, knowledge of pedagogy also includes curricular knowledge. Cochran et al. (1993) asserted that they placed more emphasis on knowledge of students and environmental contexts than Shulman. Knowledge of students comprises students' ages and developmental levels, motivations, abilities and learning strategies, attitudes, and prior conceptions of the subject they are learning (Cochran et al., 1993). Furthermore, knowledge of environmental contexts refers to teachers' understanding of social, political, cultural, and physical environmental contexts that affect the teaching and learning process.

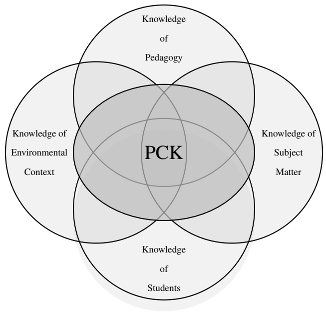


Figure 2.3: PCKg Model of (Cochran et al., 1993)

Based on Grossman (1990) and Tamir (1988), Magnusson et al. (1999) constructed a PCK model for science teaching. As shown in Figure 2.4 the model comprises five components: orientations toward teaching science, knowledge of students' understanding of science, knowledge of science curriculum, knowledge of assessment in science, and knowledge of instructional strategies (Magnusson et al., 1999).

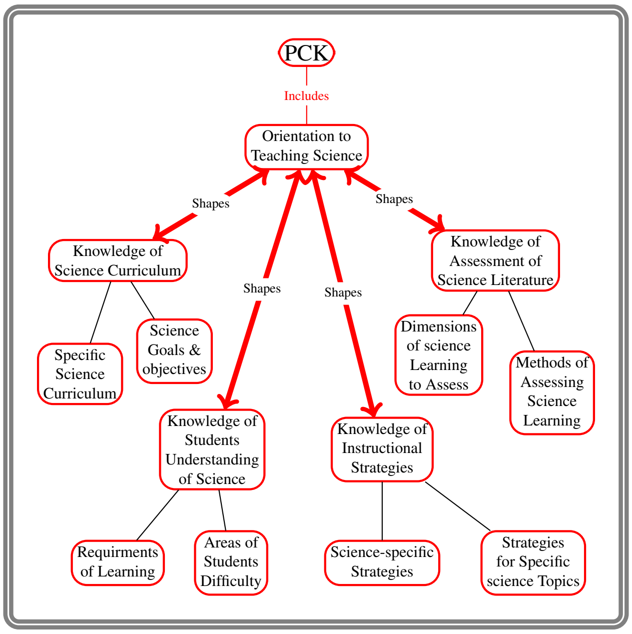


Figure 2.4: Magnusson et al.'s Components of PCK for science teaching

Lee & Luft (2008) represented all of the conceptions of PCK models belonging to different researchers, as shown in Table 2.5. This representation clearly shows that knowledge of student learning and conceptions; and knowledge of representations and instructional strategies are common components of many PCK models. This commonality indicates the significance of Shulman's first definition of PCK on other researchers since that definition was only including these two dimensions of the concept (Ozgen, 2012).

Even though PCK was initially conceptualized by L. S. Shulman and categorized into two components, through time, scholars added other components to PCK as it is observed in Table 2.5. Starting from Magnusson et al., scholars almost agreed that components of PCK are five: Representations and instructional strategies, students learning and conception, curriculum and media, purpose, and assessment.

Table 2.5: Different Conceptualizations of PCK (Lee & Luft, 2008)

	Knowledge of							
Reference	Subject matter	Representations and instractional strategies	Student learning and conceptions	General pedagogy	Curriculum and media	Context	Purpose	Assessment
Shulman (1987)	a	PCK	PCK	a	a	a	a	b
Tamir(1988)	a	PCK	PCK	a	PCK	b	b	PCK
Grossman (1990)	a	PCK	PCK	a	PCK	a	PCK	b
Marks(1990)	PCK	PCK	PCK	b	PCK	b	b	b
Cochran et al. (1993)	PCKg	b	PCKg	PCKg	b	PCKg	b	b
Ferndez-Balboa and stiehl (1995)	PCK	PCK	PCK	b	b	PCK	PCK	b
Magnusson et al. (1999)	a	PCK	PCK	a	PCK	a	PCK	PCK
Carlsen (1999)	a	PCK	PCK	a	PCK	a	PCK	b
Loughran et al. (2001)	b	PCK	PCK	b	PCK	b	PCK	PCK

Note:

a: distinct category in the knowledge base for teaching ; b: not discussed explicitly;

PCK: pedagogical content knowledge; PCKg: Pedagogical Content Knowing.

In this research, Magnusson et al.'s components of PCK model, which is based on the transformative model of PCK, are constructed for science teaching and almost incorporates components that are raised in other models will be used. From five components of PCK in Magnusson et al.'s model, the researcher was interested in four of them: knowledge of science curriculum, knowledge of students' understanding of science, knowledge of assessment in science, and knowledge of instructional strategies. Therefore, explanations of these components are given below.

Knowledge of Science Curriculum comprises teachers' knowledge about curricular goals and objectives, and applicable materials to achieve these goals and objectives. According to Magnusson et al., the knowledge science curriculum should be specially included in a PCK model, since this type of knowledge distinguishes a content specialist from a pedagogue.

Knowledge of Students' Understanding of Science refers to the knowledge teachers must hold about students to help students develop specific scientific knowledge. It includes two categories of knowledge: requirements for learning specific science concepts, and areas of science that students find difficult (Gess-Newsome & Lederman, 2001).

Knowledge of assessment in science refers to teachers' knowledge of student learning and scientific literacy that is important to assess and assessment procedures appropriate for different aspects of student learning.

Knowledge of Instructional Strategies (KIS) consists of two categories: knowledge of subject-specific strategies, and knowledge of topic-specific strategies. Strategies in these categories differ concerning their scope. Subject-specific strategies are broadly applicable; they are specific to teaching science as opposed to other subjects. Topic-specific strategies are much narrower in scope; they apply to teach particular topics within the domain of science (Gess-Newsome & Lederman, 2001).

2.6.2 Topic Specific Pedagogical Content Knowledge

Before we march into TSPCK, it is better to restate L. Shulman (1987) statement– "Comprehended idea must be transformed in some manner if they are to be thought."

This statement indicates that a teacher should transform each topic in his/her CK to be comprehendible to the learners. Teachers need to develop the awareness that teachers require the transformation of their Subject Matter Knowledge (SMK) (Geddis, 1993). Components of knowledge identified by Geddis (1993) about SMK are "Students' Prior Knowledge including misconceptions, Curricular Saliency, What makes a topic easy or difficult to understand, Representations including analogies and Conceptual Teaching Strategies" (Geddis & Wood, 1997). Because of their orientation to SMK and requiring specific considerations, these components are called content-specific components Mavhunga & Rollnick (2013). Mavhunga & Rollnick (2013) termed similar to Shulman, the capacity to transform CK of a topic through such considerations as PCK located within that topic (TSPCK).

A model developed by Mavhunga & Rollnick (2013) identified the four knowledge domains as generalized knowledge from which a teacher draws to inform PCK is shown in Figure 2.5, which is derived from Davidowitz & Rollnick (2011). On the left-hand side, the model displays a model of PCK that acknowledges the influence of four more generic teacher knowledge domains- knowledge of context, knowledge of students, SMK, and PK.

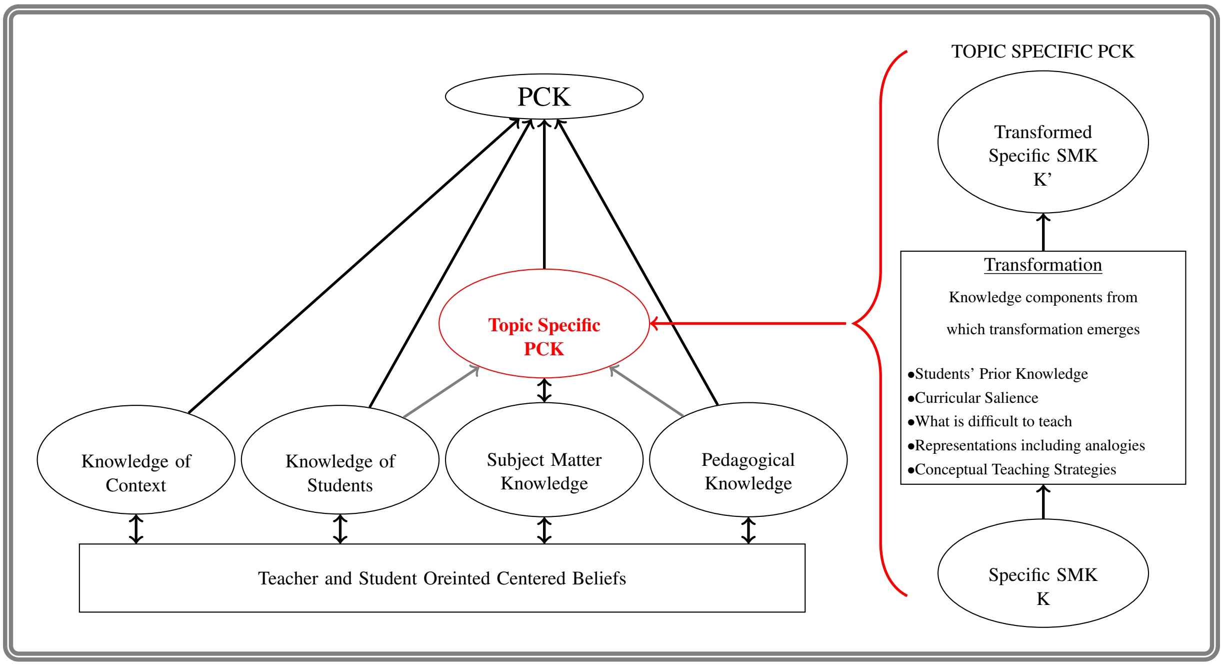


Figure 2.5: A model for Topic-Specific PCK (Mavhunga & Rollnick, 2013)

The researcher has chosen this model to explore TSPCK, because the knowledge domains reflect some similar aspects to the listed content-specific components, and because it has CK/SMK as a distinct knowledge domain. The role of CK is crucial in the discussion of pedagogical transformation, as assumed the theoretical position that CK is a necessary pre-requisite for the development of PCK (Davidowitz & Rollnick, 2011).

PCK can be elusive and difficult to articulate. However, Loughran and colleagues suggested that CoRes and Pedagogical and Professional-experience Repertoires (PaP-eRs) offered a method of capturing and portraying science teachers' PCK through concrete and meaningful examples (Loughran et al., 2012).

2.7 Development of Teachers' Knowledge

Teachers' knowledge develops through pre-service and in-service teachers' engagement with learning opportunities (Munby et al., 2001). Teachers' knowledge of teaching can be gained from various sources (Grossman, 1990). Friedrichsen et al. (2009) distinguished three sources of CK: (a) teacher education and professional development programs, (b) teachers' own KG-12 learning experiences, and (c) teaching experiences (Kleickmann et al., 2013). Lortie (1977) argued that their own school experiences shape prospective teachers' professional knowledge and beliefs.

The three types of learning opportunities differ in their levels of formalization and intentional construction Tynjälä (2008). Formal learning opportunities are organized and structured by institutions based on learning objectives; they generally lead to qualifications. Informal learning, in contrast, is not intentionally organized and takes place incidentally. It does not set an objective in terms of learning outcomes and is usually highly contextualized. It is often referred to as learning by experience or just experience Tynjälä (2008).

Qualitative studies have provided the first evidence that teacher education and professional development affect the development of teachers' KDs (CK and PCK) (Kleickmann et al., 2013). Specifically, these studies have addressed two main issues in the development of teachers' subject-matter knowledge. Even though teaching experience develops PCK, it is not sufficient alone. The experience needs to be coupled with thoughtful reflection on instructional practice, with nonformal learning through interactions with colleagues (Kleickmann et al., 2013).

Also, in Ethiopia, teachers develop their knowledge through formal and informal education. Modern formal education was introduced in Ethiopia under the rule of Emperor Menelik II in 1908 (Ahmad, 2014). During the time of Emperor Haileselassie I (1930 -1974), a significant development was registered in the education sector. One of the development was in teacher training (Kassaye, 2005). The first teacher training program was initiated with the implementation of Primary School Teachers' Training Programs at Menelik II School in Addis Ababa, and in 1950 the University College of Addis Ababa was established to train secondary school teachers (Ahmad, 2014). Following this trend, Kotebe Arts and Mechanical College (now Kotebe Metropolitan University) started teacher training program around 1970, and Bahir Dar Teachers' College was established in 1972 (Ahmad, 2014). In three regimes: Menelik, Haileselasssie, and Dergue, there was no emphasis given to the mother tongue, which is fundamental for students' understanding, instead every citizen was forced to learn the Amharic language at kindergarten and primary levels and the English language at the secondary and higher education level.

To expand the educational infrastructure, access to educational opportunities, and improve education quality, Ethiopia's government adopted an Education and Training Policy in 1994. The policy aimed to achieve four educational goals: quality, access, relevance, and equity. The training of qualified teachers is conducted simultaneously with the expansion of the education system Ahmad (2014). The Teacher Education System Overhaul (TESO) policy, which was initiated in 2003, represents a paradigm shift that officially follows the international trends of active learner-focused education (Ahmad, 2014).

Even though Ethiopian education and training policies is based on active learning, student-centered, and problem-solving approaches associated with constructivism, in its implementation, it has limitations: in preparation of authorities; in understanding and implementing constructivist learning theories; in contents that are offered for pre-service teachers at teacher training colleges and textbooks are crowded and rigid, requiring behaviorist, memorization, and teacher-centered approaches. Within this policy context, teachers are now faced with the complex task of ensuring that their students engage in meaningful learning, learn through various forms of active learning, and learn to use higher-order thinking skills. These require understanding and skills that go far beyond the past's traditional teacher-centered approaches based on the memorization of facts and information Asgedom et al. (2006). This lack of alignment may be responsible for some of the decline in the overall quality of teaching and learning and the insufficient academic achievement reported on student assessments.

The two teacher education models (concurrent and consecutive) were used in Ethiopia. The consecutive model is implemented for secondary school teachers and the concurrent model for primary school teachers. Concurrent modality uses both content and pedagogy training simultaneously, whereas a consecutive modality applies to the applicants who already have a bachelor of degree relevant to the subject area. It focuses on the "how" of teaching-pedagogical knowledge and pedagogical skills, not the "what" to teach and consists of both formal instructions and supervised practice (Serway & Vuille, 2014).

The Education and Training Policy was good, but because of a lack of well-trained workforce (both administrative staff and teachers) and material resources, the policy could not attain its one objective quality of education. Moreover, the 4-year training program is reduced to the 3-year program (Serway & Vuille, 2014), which can result in pre-service teachers' lack of their CK and sufficient time to practice teaching, which can develop their PCK. Another problem in the implementation of the education and training policy and human power and limited resource of the country is the political affiliation in assigning appropriate men power. The assignments were not based on merit. The citizen also doubts some subjects that are offered and the policy itself, for example, civic education and cost-sharing. In general, the citizen did not accept the policy as its own. The citizen should debate and comment on the policy before its implementation.

Second cycle primary school teachers were recruited from students who completed grade 10 and could not join the preparatory school. Most of these students have no positive attitude toward the teaching profession and use the profession as a temporary job opportunity, which resulted in high turnover.

2.8 Dialogic Teaching

2.8.1 Communicative Approach

Scott & Mortimer (2005) identified four fundamental classes of the communicative approach, which are defined by characterizing the talk between a teacher and students along each of two dimensions, dialogic-authoritative and interactive-noninteractive.

Interactive talk allows participation of more than one person and non-interactive talk, excluding the participation of other people (Scott & Mortimer, 2005). Interactive teaching allows both the teacher and students to verbal participation, and non-interactive teaching involves only the teacher. Thus, in interactive teaching, the teacher typically engages students in a series of questions and answers, while in non-interactive teaching, the teacher presents ideas in a 'lecturing' style (Mphathiwa, 2016).

Teacher-student interaction is a continuum between two extremes. Either the teacher hears what the student says from his/her point of view, which is called dialogic, or the teacher hears what the student has to say only from the school science point of view, which is called authoritative (Scott & Mortimer, 2005).

From the two dimensions, any classroom talk sequence can be identified as being either interactive or non-interactive on the one hand, and dialogic or authoritative on the other(Scott & Mortimer, 2005). Scott & Mortimer represented the combining of the two dimensions, as shown in Table 2.6.

Table 2.6: Four classes of communicative approach

	INTERACTIVE	NON-INTERACTIVE
DIALOGIC	Interactive/ Dialogic	Non-interactive/ Dialogic
AUTHORITATIVE	Interactive/ Authoritative	Non-interactive/ Authoritative

The four classes can be characterized as follows:

1. **Interactive/dialogic:** teacher and students consider a range of different ideas. The teacher seeks to elicit and explore the students' ideas about a particular issue.
2. **Non-interactive/dialogic:** the teacher is in presentational mode (non-interactive) considering and drawing attention to different points of view (dialogic). The teacher might adopt this communicative approach in pulling together and presenting a range of students' ideas or drawing attention to the differences between everyday and school science points of view.
3. **Interactive/authoritative:** the teacher leads students through a sequence of instructional questions and answers to reach one specific point of view.
4. **Non-interactive/authoritative:** involves the teacher in presenting a specific point of view. This approach is likely to take the form of a 'lecture' from the teacher who focuses exclusively on the school science account.

Any discussion of dialogic approaches to learning and teaching is based on the Russian psychologist Lev Vygotsky (1896-1934) who emphasized social and cultural influences on child development and especially recognized the language as the driving force behind cognitive development (Lyle, 2008). Vygotsky (1980) argued that all learning is located in a social, cultural, and historical context. He was interested in the relationship between children and others. Vygotsky has made educators see the centrality of language in children's development; this, in turn, has initiated researchers into the impact of language on learning (Lyle, 2008). Lives are only understandable through cultural systems of interpretation mediated through language, culture, and not biology (Vygotsky, 1980). Brunner (1986) builds on Vygotsky's notion by asserting that "most learning in most settings is a communal activity, a sharing of the culture."

Dialogic engagement re-emerged as a concept in the work of Bakhtin (1981). Similar to Vygotsky, Bakhtin perceive language as a social practice; all language is dialogic (Lyle, 2008). Bakhtin's concept of "dialogical meaning-making" allows the learner to play a significant role in acquiring a personally constructed understanding of the curriculum through the dialogic interchange. Dialogism emphasis the intersubjective nature of language as a social system. Dialogism argues that knowledge is something people construct together rather than an individual possession (Lyle, 2008).

Bakhtin (1981) made a distinction between dialogic and monologic discourse Lyle (2008). A monologic teacher is primarily concerned with the transmission of knowledge to pupils and remains firmly in control of talk goals. Monologic discourse is an instrumental approach to communication geared towards achieving the teacher's goals. In contrast, dialogic talk is concerned with promoting communication through authentic exchanges.

What is now seen as a monologic style of discourse structure between a teacher and pupils known as the IRF is a fundamental feature of all official talk in classrooms, constituting around 60% of the teaching/ learning process. This practice, often referred to as Recitation, is understood well by teachers and plays a central part in student learning direction and control. By direct instruction, the IRF provides the basis of teaching and enables teachers to control events and ideas in lessons (Lyle, 2008).

The purpose of the Recitation is to possess knowledge and understanding through teachers' questions, which supports the traditional power relationships that tend to repeat a pedagogy based on the transmission of pre-packaged knowledge (Lyle, 2008). The effort to promote dialogic discourse styles has to overcome this dominant form of classroom interaction; this indicates that changing a classroom discourse from the traditional classroom to values talk is challenging.

Dialogic interactions between teachers and students are significant for student understanding. Mercer & Littleton (2007) proposed that Dialogic interaction can be promoted by the types of questions teachers pose. Questions can be used to:

1. test children's factual knowledge;

2. encourage students to make explicit their thoughts, reasons and understandings;
3. model ways of using language that children can appropriate for themselves; and
4. provide opportunities for students to engage in sustained interactions that enable them to articulate their understandings and clarify any misconceptions.

Types of questions asked are contextual. Alexander (2008) argues that teachers need to have a pedagogical repertoire to accommodate these different approaches to teaching. In this repertoire, strategies are included for promoting teaching talk and learning talk with teaching talk involving teachers in discussions and dialogic exchanges with their students, so their students, in turn, ask different types of questions, learn to explain, explore and evaluate ideas, argue, reason and justify, and negotiate outcomes. Alexander called this type of teaching as DT.

The term dialogic has been associated with several different classroom talk types, such as exploratory talk, argumentation, and inquiry (Lehesvuori, 2013). In the exploratory talk, students are taught how to engage critically and constructively with each other's ideas, where they can challenge and rebut different propositions while presenting alternative hypotheses Gillies (2016). In dialogic teaching, the teacher asks students for their points of view and explicitly considers them by asking for further details or writing them down for further consideration or asking other students whether they agree with the ideas (Mphathiwa, 2016).

A dialogic classroom prioritizes tolerant, inclusive, and empathetic interaction with others, as children are encouraged to offer extended contributions, build upon and question ideas, consider alternative perspectives, and justify their responses. Vygotsky (1978) emphasized that all learning is located in a social, cultural, and historical context. He was interested in the relationship between children and others. He looked at what children could do with some assistance rather than on their own. Language is central to children's development, and language has an impact on learning (Lyle, 2008). Vygotsky's notion that education always occurs in a 'ZPD' stretched between teacher and student brings the idea of dialogic relations into education. In ZPD, the teacher has to engage with the student's perspective and vice-versa to connect the development of ideas in the student to the pre-existing culture (Wegerif, 2019). Dialogue across the boundaries of languages, countries, and cultures has become an unavoidable necessity of our life in the 21st century (Grein & Weigand, 2007).

2.8.2 Principles of Dialogic Teaching (DT)

Alexander argue ”Dialogic teaching harnesses the power of talk to engage children, stimulate and extend their thinking and advance their learning and understanding”. Alexander’s five DT principles are:

- **collective:** teachers and children address learning tasks together, whether as a group or as a class;
- **reciprocal:** teachers and children listen to each other, share ideas and consider alternative viewpoints;
- **supportive:** without fear of embarrassment over ’wrong’ answers, children articulate their ideas freely; and they help each other to reach common understandings;
- **cumulative:** teachers and children build on their own and each other’s ideas and chain them into coherent lines of thinking and inquiry;
- **purposeful:** teachers plan and steer classroom talk with specific educational goals in view (Alexander, 2008).

If classroom talk does not meet the five conditions above, it is not dialogic (Alexander, 2008). In this research, these components will be looked at in the second cycle primary school physics classroom from video-based observation.

Talk by teacher and peers in the class has the power to stimulate and enhance students’ thinking and advance their learning. These can be done when teachers engage in dialogic teaching practices when they actively listen to students, probe, challenge, and scaffold their understandings while encouraging them to explicate their reasoning and thinking. Similarly, students engage in dialogic exchanges when they share ideas, listen to others, and challenge alternative ideas while being prepared to substitute others’ ideas for one’s (Gillies, 2016).

Dialogic teaching and learning have got attention in science education as potential practices that afford students with more significant authorship, meaning, and more equitable opportunities to learn (Resnick et al., 2015; Kumpulainen & Rajala, 2017). The critical features typically associated with the dialogic approach to science education entail providing students with opportunities to negotiate their everyday and scientific reasoning, manage alternative viewpoints, appropriate the cultural norms and discourses of the discipline, and build a positive attitude toward science Resnick et al. (2015).

Many would agree that in a global era, learning to dialogue with, listen to, and learn from others who are different from oneself is an essential and necessary skill for work, family life, and citizenship in a globalization world (Brindley et al., 2016). More practically, recent teaching and learning trends have publicized dialogic approaches and brought them into popular discussion (Brindley et al., 2016).

Nevertheless, the research indicated that more monologic approaches remain the most common form of classroom communication. Because of such developments, changing the dialogic's classroom communication structure appears challenging to achieve (Alexander, 2008; Brindley et al., 2016). Dialogic teaching demands most of the teachers' subject knowledge and skill Alexander (2008). Rote, recitation, and expository teaching give teachers security. They enable teachers to remain firmly in control of classroom events and the ideas with which a lesson deals. They keep power firmly in teachers' hands as teachers. They reduce the risk that teachers' subject knowledge limits will be tested, still less exposed. They limit awkward questions about evidence, truth, and opinion that interrupt information flow from a teacher to students. In contrast, dialogic teaching challenges not only students' understanding but also the teacher's understanding. It demands that teachers have a secure conceptual map of a lesson's subject-matter and give children greater freedom to explore (Alexander, 2008).

Dialogic teaching is an approach that uses the power of talk in teaching and learning. DT supports any teaching methods the teachers use in their class in any context; this indicates that DT is not a single method, and it supports different teaching methods. It is applied/used in any teaching method. Any method: lecture, demonstration discussion-question, answering, and others can be enhanced by a quality talk between a teacher and students. Therefore, a teacher has to have knowledge of DT to make her/his classroom talk collective, reciprocal, supportive, cumulative, and purposeful. Therefore,DT contributes to Teachers' Knowledge domains, especiallyPK and PCK.

Ethiopia's education and training policy recommends active learning, student-centered, and problem-solving approaches associated with constructivism. However, in class, teachers experience the behaviorist approach, and the textbooks initiate a teacher-centered approach. Therefore, this study will explore how teachers experience dialogic teaching, emphasizing social constructivism learning theories, in their classroom.

2.9 Summary

It is evident that CK is the base for PCK, and PCK is the most important domain of teachers' knowledge, which makes a teacher different from the subject expert. Even though the same, models of PCK components developed by different scholars are different. Some scholars even forget that PCK is integrated or transformed from subject matter knowledge, pedagogical knowledge, and contextual knowledge and includes them in components of PCK. For example, in L. S. Shulman conception of teachers' KD, PCK and curriculum knowledge are seen separately, but after (L. S. Shulman, 1986) curriculum knowledge is seen as a part of PCK (Erduran & Jimenez-Aleixandre, 2008). According to Erduran & Jimenez-Aleixandre, teachers' knowledge domains are content knowledge, pedagogical knowledge, and pedagogical content knowledge. Others consider contextual knowledge, pedagogical knowledge, and or content knowledge as components of PCK, which are basically from which PCK is transformed or integrated. Therefore, it needs a consensus on components of PCK.

Content knowledge is the base for teaching, but teaching could not be satisfied only by holding content knowledge alone. Novice teachers have limited content knowledge, and they can master their content knowledge through experience. Pedagogical knowledge of a teacher is the second important component of teachers' knowledge. Teacher's PK makes a teacher has an understanding of how students can construct their knowledge. A teacher could not conduct teaching/instruction in a comprehensible manner unless he is knowledgeable in how human learns; he can motivate his learner; he makes the teaching-learning environment conducive and etc.

Having CK and PK that are fragmented and placed separately is not sufficient for teachers to run the teaching and learning process in their class. These two knowledge domains, including context knowledge, should be interwoven; this is why novice teachers face difficulties in presenting their content knowledge. The three knowledge domains should be integrated or transformed. Novice teachers may learn different teaching methods, classroom management, how students learn, and the contents of their subject area. However, they may not learn how to convey their subjects' specific topic, representation they use to instruct, students' difficulties, and misconception show to assess understanding of students on a given topic and the existing contexts. They can learn all these through experience, practice-based training (teacher development program), and reflection from others. So, PCK, whether' reflection or transformation of the other domains, is the most important component of teachers' knowledge.

Moreover, classroom discourse is the other determining factor for students' understanding. Research shows that dialogic teaching enhances students' understanding and critical thinking. In dialogic class, students articulate their idea without fear, build on their own and each other's ideas, and build their social relations.

Concerning DT, different terms are used interchangeably, for example, dialogic interaction. However, DT is not the two extremes of the two dimensions of communication. In DT classroom, we cannot say only dialogic and interactive communication approaches are employed. A teacher may use a monologue and non-interactive communicative approach for course, topic, section, demonstration, or introduction. Also, a teacher uses a monologue and non-interactive approach to conclude the lesson by revealing scientific ideas. In DT, even though dialogic interaction may be the most important and dominant part of the communication approach, another continuum of communication-suited approaches is employed.

What Alexander (2008) argues is that if a talk does not meet the five features of DT it is not dialogic, may make DT ideal, which cannot be achieved. In every talk in class, we may not address all five features of DT. Therefore, what Alexander (2008) argues is hypothetical, which cannot be realistic. Moreover, the DT approach supports any teaching methods of teaching rather than being a separate method of teaching.

In general, numerous studies were done on teachers' knowledge domains and their impact on students' achievement and understanding. A large body of research has also been done on how DT makes a difference in science students' achievement, understanding, and critical thinking. These studies did not address exploring teachers' knowledge domains and implementation of DT in the SCPS teachers' class, especially on topics: Newtons' law of motion and graphical representation of motion. Therefore, this study explored SCPS physics teachers' knowledge domains and the implementation of DT in their classes.

2.10 Conceptual Framework for the study

In this section, the researcher described how he developed the study's conceptual framework and how the framework has been used and used to guide and inform the research. The central phenomena in this Study were Teachers' KDs and the implementation of DT in the Physics classroom. In this study, the three teacher's knowledge domains: CK, PK, and PCK and implementation of DT in second cycle primary teachers' class were explored.

As shown in Figure 2.6, the framework includes domains of teachers' knowledge domains (CK and PK) that are transformed into PCK and principles of DT. The researcher used the framework as an organizing framework for the study. In the framework, since DT harness the power of talk in the teaching and learning process, he considered DT as an approach that supports teachers' PK and PCK and teachers' CK affect DT. Teachers' CK, PK and PCK influence each other.

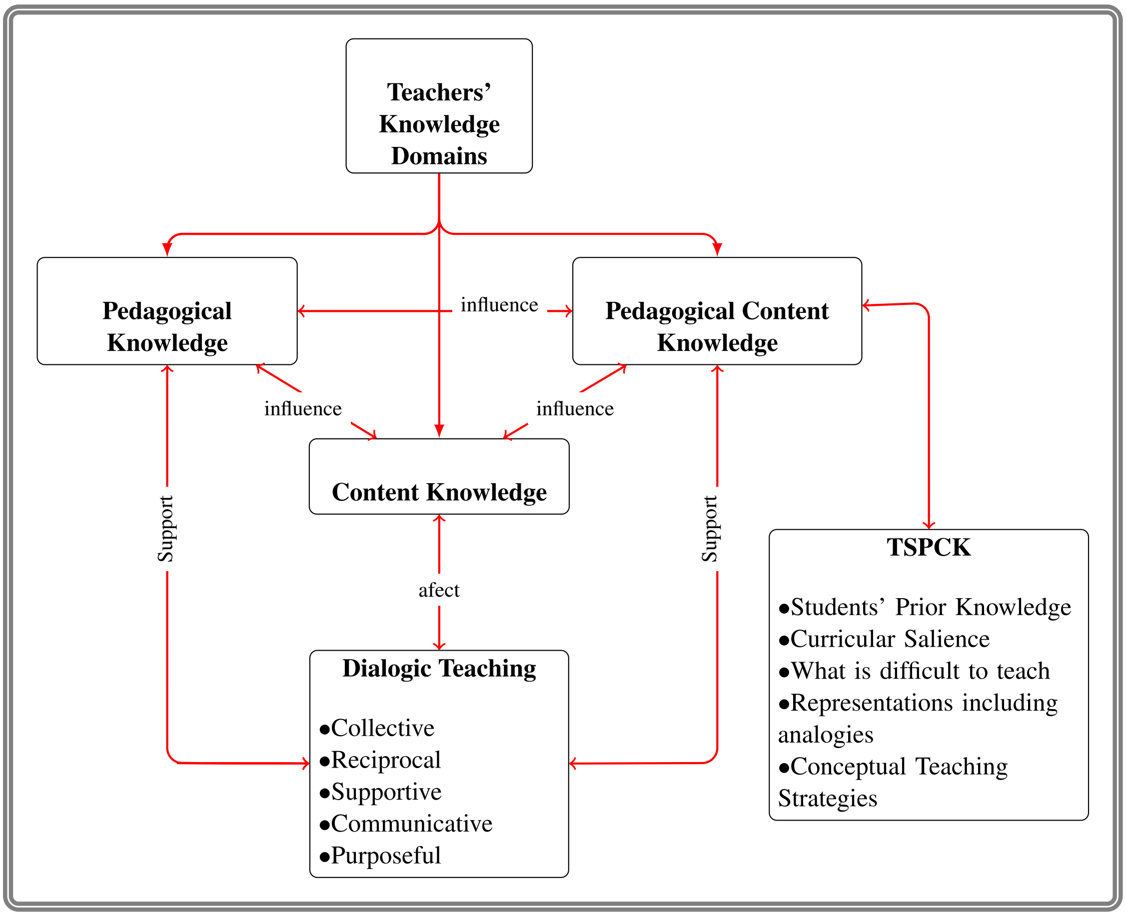


Figure 2.6: Conceptual framework for the study

Chapter 3: Methods

This chapter presented philosophical stance and justification for the research design of the study; description of the population and sample; description of instruments used for data collection and its development; procedures by which the study conducted; description of data analysis and software used; and issues of ethics, reliability, and validity.

3.1 Research Design

In educational research, there are alternative ways of conceiving social reality: objectivist and subjectivist. Subjectivists argue that the world exists, but different people construe it in different ways (Cohen & Manion, 1994); this is characteristic of qualitative research where realities are constructed and focus on understanding individuals through interactions and experiences (Cohen & Manion, 1994). Qualitative research is informed by the interpretive research paradigm which stresses inductive thinking, and exploration of issues and settings in-depth, the building of models and theory, and the use of descriptive materials from different types of data collection and analysis (Cohen & Manion, 1994; Creswell, 2009).

This study explored Ethiopian SCPS physics teacher's knowledge domains (CK, PK and PCK) and implementation of Dialogic Teaching (DT) in physics classroom. The study is, therefore a qualitative research method. This approach enables the researcher to better understand the human experience, particularly how people construct meaning and what these meanings are (Bogdan & Biklen, 1998; Merriam, 1998). Teachers' understanding of grade 7 and grade 8 physics topics: Newton's law of motion and graphical representation of motion and how they transform their knowledge of these physics topics into teachable content knowledge, and how they demonstrate DT in their classroom were explored. Therefore, the researcher had a subjectivist's stand, and the study was qualitative. This approach enables us to understand the human experience better, particularly how people construct meaning, and what those meanings are (Merriam, 1998; Mphathiwa, 2016).

Teaching is a complex process. Teachers' knowledge domains are not constructs that are easily detectable, a qualitative research method adopted in this study to collect more comprehensive data, and for an in-depth understanding of the teacher's CK, PK and PCK and implementation of DT in SCPS physics classroom.

3.1.1 Case study research

A case study is a study that "examines a bounded system or a case, employing multiple sources of data found in the setting. This case may be a program, event, an activity, or a set of individuals bound in time and place" (MacMillan & Schumacher, 2006). In this study, nine participants were invited from in-service SCPS teachers from four schools in Addis Ababa, Ethiopia. Hence, the case was nine purposely selected SCPS teachers, and the purpose was to explore teachers' KDs and their implementation of DT in their class. In this approach, the researcher usually observes the unit's characteristics to be studied to probe and analyze intensively the different phenomena that constitute the development of unit (Cohen & Manion, 1994). In this study, the researcher explored the SCPS physics teachers' Knowledge domains and implementation of DT in the SCPS physics classroom. These have been explored through an interaction with the teachers who were teaching physics at SCPSs using different identified data collection tools.

Yin (2009) states that case study is the best methodology to use when the question to be answered is "how" or "why," when there is no necessary control of behavioral events, and when the study focuses on contemporary events. How and why questions are more explanatory than other types of questions and often deal with issues that need to be explored over time. The case study allows for both the explanation and the time needed to accomplish such exploration. Yin (2009) identifies three types of case studies, in terms of their outcomes: exploratory (as a pilot to other studies or research questions); descriptive (providing narrative accounts); explanatory (testing theories). In this research, the exploratory case study design has been used to answer the research questions.

3.2 Sampling Techniques and Respondents

Since the researcher intended to explore the second cycle primary physics teachers' KD, and implementation of DT in the physics classroom, interaction with these teachers will create a rich source of relevant data. Therefore, he has chosen participants that included a group of physics teachers teaching physics at SCPSs. Because of the in-depth analysis in the case study, the number of participants is a few starting from one (MacMillan & Schumacher, 2006). Therefore, the study's sample has included nine SCPS physics teachers from four SCPSs in Addis Ababa city administration. Four of them have had one-day training on DT. From the first school three teachers, the second school four teachers, and the third and fourth schools, one teacher from each have been selected. These teachers were chosen depending on the school's proximity to the researcher, the interest of the teachers to participate in the research, and experiences of the teachers beyond three service years. More than three years experienced teachers were chosen to have teachers who have accustomed to the school environment. Therefore, the study required interested and regularly available teachers, making the sampling technique purposive and convenient. Initially, a total of 12 teachers have been approached from five schools that are near the researcher's address. These teachers were informed about the research, their benefit from the research, and their right to leave the research. From these teachers, nine of them have shown their interest and signed consent form, and three teachers did not show interest.

Every teacher's classroom was the same in dimension and found on the third or fourth floor of the building. The classroom designs are the same. Every classroom was susceptible to disturbance from the corridor when other students leave their classrooms for a break and come from break. In every class, there were no teacher's chair and table. Every teacher's school has a pedagogical center. There are charts and figures in pedagogical centers, and the teachers have access to prepare teaching aids from local materials in the center. What made the teachers differently was the class size, which ranges from 27 to 60.

The two groups (teachers who have trained on DT and have no training in DT) of teachers were chosen to compare their knowledge domains and their implementation of DT in their physics class qualitatively.

3.3 Data collection Instruments

The study adopted several data collection methods to explore physics teachers' domains of knowledge (CK, PK, and PCK), and DT in the physics classroom. Instruments used to collect data for this research were: video-based classroom observation, teacher's interview, teacher's questionnaire, content representation template, and lesson planning. These instruments have generated qualitative data. Table 3.1 lists the purposes for data collection and tools that have been used for data collection strategies.

Table 3.1: Purposes for and Instruments of data collection

Purpose	Research Question	Instrument
To explore DT	RQ 1	• Classroom Observation
To explore CK	RQ 2	• Questionnaire, • Classroom Observation
To explore PK	RQ 3	• Questionnaire, • Classroom Observation • Interview
To explore PCK	RQ 4	• CoRe template, • Lesson plan, • Classroom Observation, • Questionnaire
To compare teachers' who trained and untrained on DT with respect to their KD and implementation of DT in their class. DT	RQ 5	• Questionnaire, • Classroom Observation, • interview, • CoRe

3.3.1 Classroom Observation

It involves the direct observation of phenomena in their natural setting and typically divided into naturalistic observation and participant observation. Naturalistic observation has no intervention by a researcher. It is only studying behaviors that occur naturally in natural contexts, unlike the artificial environment of a controlled laboratory setting. Importantly, in naturalistic observation, there is no attempt to manipulate variables. It permits measuring what behavior is like (Mphathiwa, 2016).

Video-based classroom observations have been held while each selected second cycle primary physics teacher teaches topics she/he would teach on the observation days. Two video cameras have been used in a class. One camera has been recording the whole class (all students), and one camera has been following the teacher. The second camera has been recording the teacher's activities and utterances. The researcher used both cameras to explore how physics teachers' KD and DT were manifested in physics classrooms. Classroom observation is the best way to analyze what is going on in the real class. Therefore, video-based classroom observation helps to answer research questions (1–5). During each observation, there was no intervention by the observer. Therefore, the observation was naturalistic. The behavior of the teacher has indeed been influenced because of the cameras in the classroom. The researcher can overcome this through repeated classroom-observation, and then, the teacher forgets the camera's existence through time. All teachers have been observed at least three times in their classes. The two last observations were used for analysis, while the first observation was used to familiarize the teacher with cameras.

3.3.2 Questionnaire

The questionnaire helps to measure the specific characteristics or opinions of the respondents. The questionnaire helps to dig out what is latent about the teacher during a classroom observation. The questionnaire will be a self-completion teacher questionnaire and have two parts (see Appendix C). In this study, the questionnaire has 22 open-ended research questions to answer research questions (2–5).

3.3.3 Content Representations (CoRe)

A CoRe template is a tool developed by Loughran et al. (2004) to capture and portray PCK. A CoRe is developed by asking teachers to think about what they consider to be the ”big ideas” associated with teaching a given topic for a particular grade level(s) based on their experience of teaching that topic (Loughran et al., 2012). A CoRe displays and discusses the teachers’ understanding of certain aspects of PCK, which are most closely attached to a topic. CoRe, as a research tool, helps to access teachers’ understanding of the content and is also a way of representing this knowledge.

A CoRe provides an overview of how a given group of teachers conceptualizes the content of a particular subject matter or topic. It is developed by asking teachers to think about what they consider to be the ”big ideas” associated with teaching a given topic for a particular grade level(s) based on their teaching experience. These big ideas become the horizontal axis of a CoRe. There is no defined number of big ideas. Too few big ideas suggest that too much may be encompassed in a single big idea while too many big ideas suggest the topic maybe being ”broken down” into ”chunks” of information (Loughran et al., 2012).

The big ideas are then probed and quizzed in different ways through the prompts listed on the left-hand side column of the CoRe table. There are eight prompts:

1. **What you intend the students to learn about this idea.** This is the first prompt in the vertical axis of a CoRe and is a starting point for ”unpacking” the big ideas.
2. **Why students need to know this** In the multitude of competing for curricular decisions that teachers face, deciding what to teach must be linked to why it is important to be taught.
3. **What else you might know about this idea (that you don’t intend students to know yet)** Teachers often make difficult decisions about that which needs to be included, and that which needs to be excluded, for students to begin to develop an understanding of the topic/theme.
4. **Difficulties/limitations connected with teaching this idea** Teachers come to de-

velop and respond to insights they gain about potential difficulties when teaching a particular topic. In science, this is particularly borne out in the research into alternative conceptions/misconceptions, and the limitations of such things as models and analogies in promoting understanding or explaining phenomena.

5. **Knowledge about students' thinking which influences your teaching of this idea.** This prompt is important for helping to make explicit that which teachers have come to know through their experience of teaching the given topic, and how that knowledge influences their thinking about their teaching.
6. **Other factors that influence your teaching of this idea** This prompt in the CoRe is aimed at unpacking teachers' contextual knowledge about students as well as their general pedagogical knowledge to explore how these might influence how they approach and construct their teaching.
7. **Teaching procedures (and particular reasons for using these to engage with this idea)** 'teaching procedures' is important in differentiating between different aspects of planning for, and the teaching of, subject matter. The teacher may well use an activity to introduce students to a topic and as such, the activity can be applied to a situation "as is". Teaching procedures are tactical in that teachers choose which procedures to use, when, how, and why in order to promote different aspects of learning. On the other hand, a strategy incorporates an overall approach such as 'building a classroom environment that supports risk-taking" or "sharing intellectual control'.

(Loughran et al., 2012)

In this research, CoRe was used to explore PCK. Similar to Mphathiwa (2016), each teacher explored big ideas on topics Newtons' laws of motion and graphical representation of motion they have been teaching in the first semester of the 2018-2019 academic year. CoRe template has eight open-ended questions for each big idea and is used to answer research questions 3. Sample CoRe for grade 8 physics is shown in Appendices A.1 and A.2.

3.3.4 Lesson planning

Each participant who filled the CoRe template developed lesson plans using a lesson plan format that is shown in Appendix B.1. The teachers were asked to prepare two lesson plans for two big ideas; this triangulated the data collected by CoRe to explore teachers PCK. Therefore, it helps to answer the research question 3. Moreover, the lesson plans' data explore PCK further by establishing the extent to which the teachers' plan is coherent with the purpose of the lesson, their interpretation, and representation of the content.

3.3.5 Interviews

Interviews are like discussions that researchers use to explore informants' experiences and interpretations (Hatch, 2002). Semi-structured interviews have been used. It allows the researcher to lead the interview, have a time frame for interviewing, and record the interviews if desired (Hatch, 2002). They are in-depth as they go deeper into the understanding of informants, allow probing, are flexible and exploratory and are like conversations (Hatch, 2002; Merriam, 1998).

Interviews were conducted as follow-ups to the classroom observation, the questionnaire, the lesson plan, and the CoRes. The interviews also make bright ideas raised in teachers' classes. Also, it helps for triangulation purposes. Interviews have been administered to 5 teachers using audio recordings because of their responses to other instruments. The interview questions emerged from the responses of the teachers to other instruments.

3.4 Data Collection Procedure

Figure 3.1 illustrates a summary of the data collection tools and procedures. After the proposal's approval, research permission looked for from the respective authorities, and the respondents have completed and signed a consent form. After permeation, data collection instruments have been developed and then validated with the comment of professionals such as colleagues and supervisors. After the validation of the instruments, data were collected.

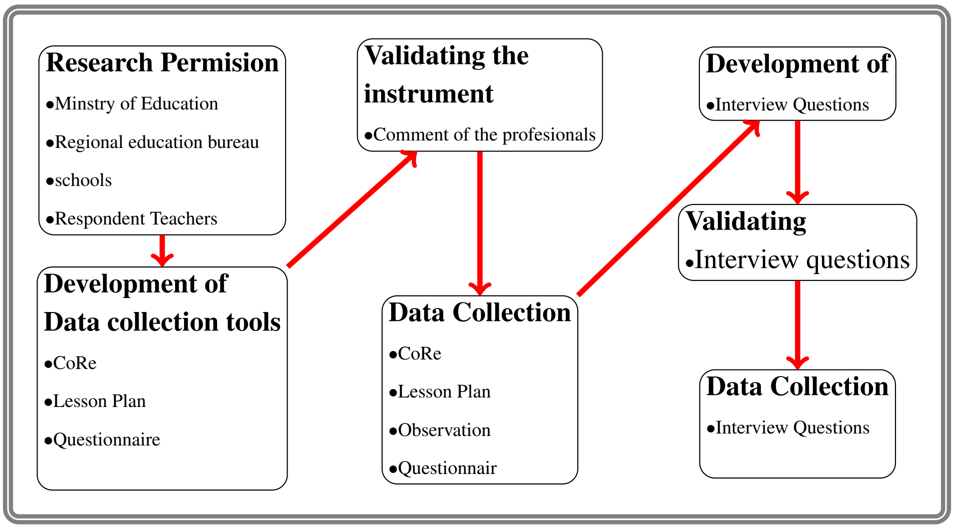


Figure 3.1: Summary of data collection

As it is indicated, after data collection, there was the development of instruments (interview questions), because there are interview questions that were emerging from data collected using other instruments and their analysis. Therefore after interview questions were developed, data were collected again using interviews.

3.5 Data Analysis

Data analysis is a systematic search for meaning, processing data to be communicated to others. It involves "organizing and interrogating data in ways that allow researchers to see patterns, identify themes, discover relationships, develop explanations, and make interpretations, mount critiques, or generate theories" (Hatch, 2002). There are no clearly laid-down procedures for analyzing data in qualitative analysis, no right or wrong way to do it (Hatch, 2002). The complexity of analyzing qualitative data is compounded by the form of the data, mostly descriptions or narratives of objects, events, or processes.

There are various ways of making sense of analyzing qualitative data. It includes a deductive process of categorizing data and identifying relationships (Hatch, 2002; Pope et al., 2002). The deductive analysis is undertaken with a theoretical framework as background (Pope et al., 2002). In this study, models for teachers' knowledge domains Gess-Newsome (1999), for PCK Magnusson et al. (1999) and for principles of

DT Alexander (2008) adapted to develop a modified model for PCK and DT. This model is continually referred to inform the data analysis. Interaction between the incoming data and theoretical ideas from the literature will facilitate appropriate coding and categorizing the data to make the findings more meaningful.

Themes, consistencies, and exceptions in the data collected (Hatch, 2002) were scanned. Data were examined, classified, and organize to address the primary objectives of the study. These were done in the classroom observations, questionnaires, CoRes, and lesson plans. The analysis explored the teachers' KDs and the implementation of DT in physics classroom based on Alexander (2008)'s principles of DT. Data analysis was performed simultaneously with data collection, allowing for shaping the direction of future data collection and analysis based on what is or is not being found (Hatch, 2002). In this analysis, NVivo in scanning themes, R to analyze frequencies and plot bar charts, and Latex to write the report were used. Data collected were scanned for features of DT, Components of teachers' CK, components of teacher's PK, and components of TSPCK using NVivo. In comparing the implementation of DT, R was used to compute frequencies and plot bar chart.

3.5.1 Analysis of Classroom video-based observation

In the analysis of classroom video-based observation, present analysis of teachers' activities in the second cycle physics classroom was used. The video-based observation was transcribed verbatim. Data were sorted and identified into patterns, themes, similarities, and differences to help interpret the data concerning Teachers' content knowledge, pedagogical knowledge, pedagogical content knowledge, and principles of DT.

3.5.2 Analysis of CoRe

CoRes have been used to present a brief analysis of each respondent's representation of PCK on Newton's laws of motion (grade 7) and graphical representation of motion (grade 8). For each respondent, the different kinds of knowledge emerge from subject matter transformation, which includes curricular saliency, content representations, what makes a topic difficult to teach, students' prior knowledge, and conceptual teaching strategies for each big idea were explored. The researcher has adapted Mavhunga & Rollnick (2011)'s rubric, which is shown in Appendix A.3to score teachers' responses in the CoRe.

3.5.3 Analysis of the questionnaires

In an analysis of the questionnaires, data were sorted, identifying patterns, themes, similarities and differences in the responses, to help me interpret the data, with respect to goals for teaching grade 7 Newton's law of motion and grade 8 graphical representation of motion, teacher competencies needed in the teaching of Newton's law of motion and a graphical representation, teachers' awareness of students' prior knowledge, curricular saliency, challenges of teaching the topic, knowledge of students, points of misunderstanding and misconceptions about the topic and with respect to elements of dialogic teaching.

3.5.4 Analysis for lesson plans

In the lesson plans analysis, the researcher has looked at all the parts in each lesson plan and compare them between the respondents to draw out patterns, similarities, and differences.

3.5.5 Analysis of Interview

The interview has been used to triangulate the analysis made by other techniques: video-based observation, questionnaires, CoRes, and lesson plans.

3.6 Ethical Considerations

Educational researchers work on students, teachers, and in general, on the human being. Therefore, educational researchers should respect their respondent's right, minimize or avoid any risk or what will make the respondent disadvantageous, and pay an incentive that can compensate for the time lost by the respondent. Participants reveal what goes on behind the scene in their daily lives; they trust researchers with intimate details of their lives (Cohen et al., 2000).

Therefore, it is essential to follow ethical procedures when working with human beings as subjects in the research. Ethical considerations include informed consent, confidentiality, anonymity, privacy, and fairness (MacMillan & Schumacher, 2006). Hence, the research proposal has been submitted to the Department of Science Education for approval, and certain strategies ensured that the participants' rights will be protected. These include permission, informed consent, confidentiality, anonymity, and protection from harm. It was used to support data collected by teachers' CoRe.

3.6.1 Permission to conduct research

Permission has been sought from the Science and Mathematics education department, City education bureau, and Schools to access teachers and schools. After getting permissions from these respective offices, the researcher has provided the respondents with the precise nature and scope of the research: the aims, design, methods, and procedures to be used, nature and size of samples, the activities to be observed, subjects to be interviewed, time involved, arrangements to guarantee confidentiality, how the findings would be disseminated, a timetable and whether assistance would be required in the organization and administration of the research. Only those who agreed to participate in the study were included in the study.

3.6.2 Informed consent

Consent protects and respects the right of self-determination of the participants in the research. Participants (SCPS physics teachers) were invited to be included in the study and informed before data collection. They have given the right to refuse to take part or withdraw once research had begun (Cohen et al., 2000). Briefing sessions have been held with the participants to ensure that they knew what will be involved in the research, be fully aware of the research's purpose, and understand their rights. They have completed and signed a consent form to indicate whether they would or would not participate.

3.6.3 Confidentiality and anonymity

Information obtained from the participants has been used as agreed during informed consent. Respondents would not be identified or presented in an identifiable form. Their anonymity has been preserved at all times by ensuring that no names are used in the written report. Teachers and schools have given pseudonyms so that the researcher was the only one who knew how to identify them. Data were kept safe and confidential.

3.6.4 Protection from harm

Participants have been protected from any kind of harm, physical or psychological. During the interview, both English and Amharic languages were used. The languages were as transparent as possible, neutral, respectful of the respondent.

Chapter 4: Data Analysis and Results

4.1 Introduction

This chapter attempted to address research questions that were intended to uncover how SCPS teachers conceptualized and portrayed their knowledge domains (CK, PK, and PCK) on grade 7 and 8 topics Newton's law of motion and graphical representation of motion and how they demonstrate DT in their class. Even though there was a difference in depth, these two topics are included in each grade content.

Table 4.1: Summary of Teachers' Demography

Teacher	Age	Class size	Qualification	Service	Gender	Training
01	26 years	48	Dip.	6 years	F	Yes
02	25 years	27	Deg.	3 years	F	Yes
03	26 years	27	Deg.	4 years	M	Yes
04	32 years	30	Deg.	8 years	M	No
05	25 years	38	Deg.	6 years	F	No
06	28 years	40	Dip.	11 years	F	No
07	27 years	34	Deg.	3 years	M	No
08	32 years	60	Deg.	10 years	F	No
09	33 years	60	Deg.	12 years	M	Yes

Conceptions and portraits of each of the nine in-service teachers that constitute the case study were provided. Each teacher was introduced, and their knowledge domains and classroom communication approach were examined using CoRe, classroom observation, lesson plan, questionnaire, and interview.

As depicted in Table 4.1, every teacher has a first degree in physics except two teachers who were attending universities for their degree and will complete it in one year. Therefore, the teachers are almost on the same level in their qualification; and they are assigned to teach in SCPSs. Five teachers are females, and four are male.

There were two groups of teachers who were participants in the research. The first group was those who attained training in DT, which was offered by the researcher, and the second group did not attend the training. Contents of the training were:

- Theories and principles of Dialogic teaching,
- Merits of dialogic teaching in teaching physics and
- How to implement Dialogic teaching in physics class.

4.2 Analysis of Implementation of Dialogic Teaching in Physics Class

4.2.1 Introduction

This section uncovers how the SCPS teachers demonstrate DT in their class. Each teacher's video-based classroom observation was transcribed and analyzed. Based on Alexander (2008)'s five principles of DT, the teacher's implementation of DT was analyzed.

4.2.2 Dialogic Teaching in Physics Class

Teacher 01

Just when the class starts, the classroom environment was not conducive to DT. From outside the class, students who were moving here and there were shouting. However, as time went on, the students' shouting ceased because all students returned to their class from break. The layout of the classroom was arranged for collective group work.

The teacher has stopped a student from explaining her idea because the teacher did not consider what the student was answering was not relevant to the question. The script was:

teacher:	What did we learn yesterday?
Student:	We learned about Newton's laws of motion: Newton's first law, Newton's second law, and Newton's third law.
Teacher:	Stop

The teacher's feedback was negative. It discourages students not to express themselves freely, which shows the class was not supportive.

The teacher starts the lesson transition with group discussion. Questions prompted for group discussion were not well-structured to provoke thoughtful students' answers and build students' prior knowledge (Alexander, 2008). The question was: "What is Newton's first law of motion?" Students at this level are not accustomed to this law. The concept is new to them. It was better if she started with what they knew. For example, What happens to you while traveling by bus if it stops its motion suddenly? While you are riding a bicycle, if you hold the break unconsciously, what will happen to you? Or What will happen to you if you are running and try to stop suddenly? Students are accustomed to these phenomena in their daily life. After their answer to the question, the teacher can gear toward the topic of Newton's first law of motion.

Even though a few were not active participants in the discussion, students express their idea without fear of embarrassment from their colleagues or their teacher. Almost every student discussion was about the topic (question). The teacher was moving among the groups to support students' discussion. At the end of their discussion, each group representative reflects on their results, which shows the class was supportive, cumulative, and purposeful. The reflection lack was that the teacher did not encourage other groups to support or refute the idea of the reflecting group, which indicates that the class lacks the reciprocal feature of DT

In teacher-student interaction, students explain their viewpoints without fear, and the teacher can build another question based on their response. The transcript is:

Teacher	Why are we forced to move forward while a car stops, and backward when it starts to move? and why car drivers use safety belt?
Student	... because the air inside the car forces us to move forward when the car tends to stop and ... forced to move backward ... because the car starts suddenly without our conscious
Teacher	What if there is no air inside the car? let us say we close all the windows.
Student	What about the air in the car?
Teacher	What if we don't allow air to enter the car? Let us say we closed all opening. As you said when the car stops the air pushes us backward. Assume there is no air.
Student	When the driver brakes, to save the life of a person in front of the car, we are forced to move forward. Drivers use a safety belt to prevent his face from harm (injury). ..., he has to tie the belt. The other thing is he may touch what is unknowingly what is not recommended and impinge on them.

From this transcript, we observe that the students were free to discuss and reflect their points of view, based on students' provoking answers, the teacher has been prompting other questions, making the class think loud. However, they did not come to a common point of view, which indicates that the discussion was supportive in contrast to during the lesson introduction.

The teacher has been steering the whole class not to discuss other topics, which are not topics of the day, such as Newton's third law, which made the class purposive, however the way the teacher treated a student was not supportive in saying "stop." Instead, it was better if the teacher appreciated their idea and informed that the topic would be discussed in the future.

To make participants in the discussion, the teacher has been giving a chance to students who did not hand-up randomly. Teacher's feedback was sometimes informative and none-discriminating praise (thank you, very good and excellent). The teacher has managed her time economically in three phases of the lesson (introduction, transition, and conclusion). In the introduction and conclusion phases of the lesson, dialogic teaching features were not observed this much. Whereas in the transition phase, even though they have defects, dialogic teaching features were observed.

Teacher 02

The classroom layout was for the whole class discussion. The teacher started the class by writing notes, which lasts for 10 minutes, which does not facilitate dialogic teaching. The teacher asked questions about the previous lesson, such as ”What is speed? What is velocity?” and the students have been responding. The teacher has been looking for the correct answer. Ones, the students answered the correct answer; she did not look for other alternatives. The pattern of discourse between teacher and students was triadic ”IRE”(Mortimer & Scott, 2003).

After 12 minutes elapsed, the teacher started the day’s lesson by asking questions: What is uniform motion? What is uniform velocity? No one tried to answer the question, and the teacher did not encourage and helped the students answer the question. Then, the teacher herself defines what uniform motion is. The class was highly teacher-centered, and students kept passive. Therefore, the communicative approach was almost non-interactive/authoritative.

Every question posed was closed-ended and had no weighting time, and many questions were asked at a time. These could not make the students think aloud, support students to explain their point of view, make students learn from each other, and elicit students’ understanding of the concept. Even though a few students provoke other questions to extend discussion for more understanding, the teacher did not probe other questions other than looking only for correct answers.

She has been using praise that did not discriminate; rather, she has been saying very good, excellent thank you, etc. in her feedback. Her feedback was not informative. Repertoires of talk for teaching she has been using were more of recitation and instructional.

These indicate that the class lacks all dialogic teaching (collective, reciprocal, supportive, and cumulative) features, except it was partially purposeful. The teacher has been working to cover the content in the lesson. The content on the topic did not cover adequately. For example, the velocity-time graph and displacement time graph properties such as slope and area under the curve were not mentioned in the teacher's presentation. Therefore, the teacher did not demonstrate dialogic teaching in her class. Instead, she was using traditional repertoires of talk for teaching, in which teacher's talk was dominant and different viewpoints were not addressed (Alexander, 2008).

Teacher 03

The teacher started by delivering concise notes within a short time; times for the three phases of the lesson: introduction, transition, and conclusion were efficiently used. The classroom was conducive for group discussion. These facilitate the class for dialogic teaching.

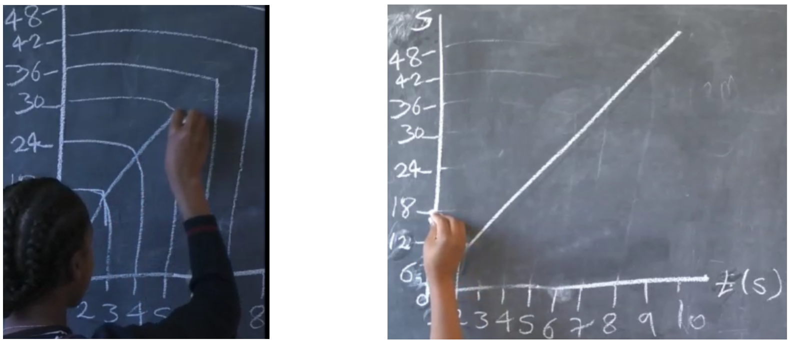
The teacher has been asking questions in the previous lessons, including students' mathematical knowledge, which helps them build their knowledge on what they know. Therefore, in the introduction phase, the discourse was more ofIRF. In the transition phase of the lesson, almost the class was teacher-centered. The teacher has presented all content of the topic. He has been raising different ideas on the topic, which were all scientific. All contents on the topic were addressed very well. Students were passive, except they responded to questions posed by the teacher during his presentation. Questions raised in the class were not challenging students' thinking. During the transition phase of the class, students were not encouraged to ask questions. Therefore, the classroom communication approach observed was more of non-interactive/Dialogic.

Hence, most dialogic teaching (Collective, reciprocal, and supportive) features were absent in this class, and cumulative and purposeful features were demonstrated.

Teacher 04

The teacher started with the previous lesson by asking questions. The teacher's review was not much relevant to the lesson of the day. The teacher's review was about Newton's second law of motion, and the lesson of the day was a Graphical representation of motion. I think it is better for this topic if the teacher reviews motion: displacement, velocity, and acceleration and about the $x - y$ plane which students have learned in mathematics. Since, in graphical representation, they will plot $s - t$, $v - t$, and $a - t$ graphs and discuss their properties, which made the introduction part of the lesson not purposeful and diminish the cumulative nature of knowledge.

Teacher's closed-ended questions could not challenge students' thinking and elicit students' understanding. His feedback to students' answers was not informative and posed other questions to extend the discussion. The teacher listens to the students' answers until they fully express their idea, which made the class partially supportive. The discourse in the class was more ofIRF. Repertoires of talk for teaching were more of recitation and instructional. The classroom layout was for the whole classroom discussion; all students were facing the teacher.



(a) The first graph *(b) The second graph*

Figure 4.1: S-t graphs

Teacher's exercises comprised both closed and open-ended questions, which can probe and challenge students' understanding, which is one indicator of dialogic teaching (Alexander, 2008). However, the teacher did not handle students' responses properly. The teacher did not help students while they were demonstrating their work on the blackboard. For example, his support was absent when a student plot a displacement-time graph, showing her steps clearly, but due to different scales in her axes, the line drawn was not straight, as shown Figure 4.1a. The teacher's feedback was evaluative and not informative. He praises by saying very good and asking an evaluative question, "Is the graph correct?". Another student was invited to plot the graph. The student plotted a straight line first and then connected the coordinate, as shown in Figure 4.1b.

The teacher accepts the student's answer as if she was correct, and there was no pupil-pupil interaction, which made the students not share their idea. All the class was non-supportive, non-cumulative, and non-collective.

At the end of the class, the teacher asked an ambiguous question. As shown Figure 4.2, he draws horizontal and vertical axes on the board and said: "What do we call this graph?" There was no graph, but after students could not answer, the teacher said no motion. To say there is no motion, the vertical axis should be labeled displacement and the horizontal time, and there should be a horizontal line drawn, which is the graph of the motion. This unorganized question cannot provoke thoughtful answers (Alexander, 2008) and make decline dialogic teaching in the class.

Figure 4.2: Horizontal and vertical axes considered as graph

The teacher speaks to the board. This behavior affects dialogic teaching negatively (Alexander, 2008) since the students did not hear what was said and did not see his body language, and the students were tied to taking notes.

Some contents the teacher was teaching were beyond the level of the students. The teacher taught how to derive equations of motion for uniformly accelerated motion analytically, which needs knowledge of the quadratic equation, which they were not accustomed to and not in the curriculum, which made the lesson non-cumulative and non-purposeful.

Therefore, in the teacher's class, there were no features of dialogic teaching observed. Hence, the teacher didn't implement dialogic teaching.

Teacher 05

The classroom layout was for whole-class teaching. The teacher starts with the previous lesson: Newton's first law of motion, by asking questions. Most questions were low level. The teacher's feedback was not informative and prompted other questions based on students' responses to elicit students' understanding and challenge their thinking, which does not support students to chain their knowledge coherently.

The lesson of the day was "Newton's second law of motion." The teacher did not relate the topic with the daily experience of the students. She stated Newtons' second law. The lecture was the dominant method used in the teacher's class, and the teacher was focused on the curricular objectives. The discourse pattern used was more of IRF. Students were not encouraged to elicit their point of view. Also, the communication pattern used was mainly non-interactive/authoritative. What the teacher asks, the students answer in chorus. Time elapsed by the teacher to give a note of 8 lines, which took 11 minutes, was more than needed. There were a large number of students who sat idle after writing down the note.

At the final phase of the lesson, the teacher provided two problems (activities) that were solved individually. Some students were trying to solve the problem, while others were seating ideal. There was no teacher support while students were solving the problem rather than asking them, "have you finished?"

After the students solved the problem, the teacher invited them to demonstrate their work on the blackboard by calling their role number, which may help advance dialogic teaching. Teachers' feedback was not informative but rather evaluative. After the student completed solving the problem, the teacher asked the class, Is it correct or not? Moreover, if the class says no, the teacher gives a chance to others.

Therefore, the teacher's class did not comprise the dialogic teaching features (collective, reciprocal, cumulative, and sportive) except a purposeful feature.

Teacher 06

The teacher started the class by asking questions about the previous lesson, as the transcript shows.

Teacher	In the previous lesson, we learn about what?
Student1	Newtons second law
teacher	We learn about Newtons law of motion. There are three types of Newton's laws of motion. What are they?
Student2	Newtons first law of motion.
Teacher	the second
Student3	Newton's second law
Teacher	The third one is?
Student4	Newton's third law

These questions are close-ended. They do not challenge students' thinking. Teachers' feedback was not informative and elicited students' understanding by posing other questions, which challenges students thinking, based on their response; instead, she accepting or repeat students' answers. These indicate that there were no features of dialogic teaching in the introduction phase of the class.

In the transition phase of the class, the pattern of discourse was more of IRF. After the teacher explained what Newton's second law of motion, she posed a question: What is the formula of force.

Teacher	What is the formula of force?
Student1	mass times acceleration
Teacher	force is equal to mass times acceleration. What is the SI unit of force?
Student2	N (other students assuming the answer were incorrect, said here teacher chorally)
Teacher	Please calm down. What is N? (pointing to the student who answered the question)
Student3	Newton
Teacher	Newton is symbolized by N. One Newton is equal to?
Student4	One kilogram per second square (in chorus)

Teacher ... Why? How are they equal?

Student5 Force is mass times acceleration, mass is in kilogram and acceleration is in meter per second. Therefore, one newton is one-kilogram meter per second square.

The repertoire of talk for teaching used was recitation. The questions were closed-ended and did not ask in a way to be asked. Since they discussed Newton's law of motion, it was better if she asked the students to state Newton's second law of motion. Her feedback was not informative and supportive. Students' answers were not well-articulated, and the teacher also did not pose questions that would elicit their understanding of the concept, what does the equation represent.

Therefore, dialogic teaching features were not demonstrated in the class except for a purposeful feature that was partial. Instead, the teacher's class was traditional in which his idea only reflected and used recitation and instructional repertoires of the talk.

Teacher 07

The classroom layout was for group discussion, but the method used was more of a lecture method. The teacher started with the previous lesson: ”free-falling body” by asking numerous questions at a time.

”What we learn in the previous lesson?”

”What is free falling body?”

”What is kinetic energy?”

”What is potential energy?”

Without a student's response, the teacher tried to introduce the lesson of the day ”Graphs of uniform motion and uniformly accelerated motion” by asking questions. What the teacher tried to review was not relevant to the topic of the day. It was better if he had reviewed uniform and uniformly accelerated motions and $x-y$ plane, which the students have learned in grade 7 unit 4 mathematics. In these topics they are going to discuss $s-t$, $v-t$, and $a-t$ graphs. Questions posed have no thinking time and are numerous; this does not allow students to think aloud and consider what the teacher asks, no need to answer.

After reviewing the previous lesson, he introduced the lesson of the day by asking questions:

> "What is acceleration?"
>
> "What is graph?"
>
> "What is the reactant to the distance time graph?"

Again, the teacher asked numerous questions at the same instant, and some questions were ambiguous. Most of the time, the teacher provided answers to questions he posed rather than helping students to respond. His answers were not clear and out of literature. For example, he defined free fall as

> "Free falling body is through the sky come to the earth by gravitation. That gravitational speed 9.8 m/s^2."

During the lesson transition, the teacher used the lecture method permanently, except he posed questions. The day's topic was about graphical representation, but the teacher's presentation was more about velocity, displacement, and acceleration, which were explained more analytical. In his presentation of the acceleration time graph, he was plotting a-t graph for non-uniformly accelerated motion, which is beyond the students' level.

In this class, the students were not encouraged to ask questions. The repertoire of talk for teaching was recitation and instruction. Teacher's knowledge of the subject matter was also limited. In his narration about the relationship between displacement, velocity, and time, he stated that

> ... when velocity is constant displacement is constant, time is constant. In uniform motion, velocity is constant, speed changes, acceleration constant.

Moreover, the teacher argues that the graph shown in Figure 4.3 represents uniformly accelerated motion. He did not differentiate equations of motion for uniform motion and uniformly accelerated motion. He has been using an equation $s = vt$ for uniformly accelerated motion. These confirm, what Alexander (2008) argues, teacher's subject knowledge affects the classroom talk.

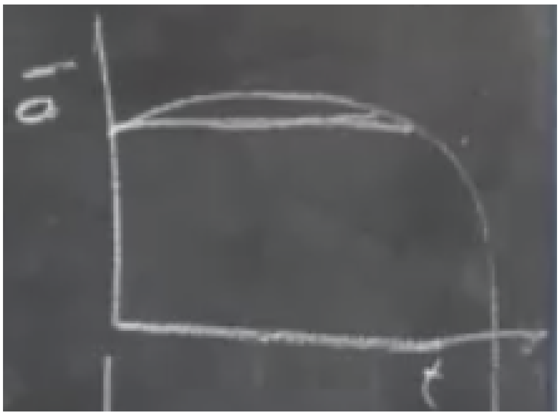


Figure 4.3: Acceleration-time graph

The teacher wasted most of his time in the introduction phase and was teaching out of the topic's content. Questions (problems) the teacher poses, as shown in Figure 4.4 were not well-structured. There is no "uniform motion acceleration" in literature. He said, "Find the graph of displacement graph." and "... acceleration graph." These indicate that the class was not purposeful and cumulative.

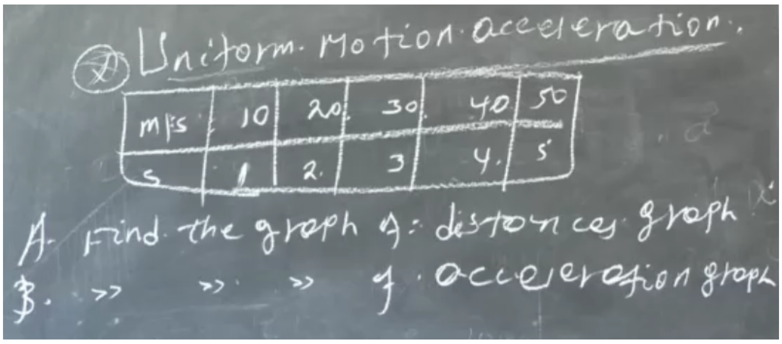


Figure 4.4: Un structured teachers' questions

Therefore, the lecture method was used in which almost all students' interaction was negligible. The repertoire of talk for teaching was instructional, and the communication approach was more of a non-interactive/authoritative one. Hence, in class, there were no features of dialogic teaching observed.

Teacher 08

The classroom layout was for group discussion. In a group, there were more than six students. Hence it was not conducive for discussion. The teacher started the class by posing questions:

Teacher	What is force?
Student1	Force is push or pull on a body.
Teacher	Clap, force is a pushing or pulling on a body. ... What is the measuring instrument of force?
Student2	What is the question? (he asked the question to be repeated)
Teacher	”What is a force measured using an instrument?”
Student2	ee (he couldn’t answer)
Teacher	”ehe” (the teacher give chance to another student)
Student3	(He could not answer)
Teacher	another student
Student4	spring balance
Teacher	clap ...

Teacher’s questions were with low cognition levels. She was looking for the correct answer, and once she has got the correct answer, she did not ask for more ideas; instead, she gave only positive feedback, which was not informative.

The class discourse pattern wasIRF. The teacher’s feedback was non-discriminatory, and she did not correct the students’ responses. For example, students listed contact forces: magnetic force, spring force, gravitational force, and electric force, but the teachers did not correct students’ answers; rather, she praised them, this indicates the teacher’s subject knowledge was limited, which affects the repertoire of talk for teaching negatively Alexander (2008).

The teacher started the day’s lesson by giving notes on the blackboard, which has taken about 15 minutes. The classroom was susceptible to interruption and could not concentrate due to disturbance from outside the class and students talking and horseplay in the class. The lecture method was used mainly during the transition phase of the class. During the lesson presentation, students answered the teacher’s question. Most students were not listening to the teacher and their peers. Some students have been talking about other issues and horseplay during the lesson presentation.

The second class was interactive, and the student's ideas were reflected. However, the teacher did not make these ideas coherent, and students agreed on one idea or did not explain them. Instead, she accepted all ideas as if they were correct; this again indicates the teacher's subject knowledge was limited, and the class lacks dialogic teaching features.

For an activity that was given for a group discussion, 25 minutes were elapsed; This made the teacher not complete the lesson's content. During the discussion, many students were not engaged in discussion; instead, they were talking and horse playing and some students were idle and bored.

After discussion, some students demonstrate their work on the blackboard. The teacher's feedback was only positive, non-discriminating, and non-informative. Hence, in the teacher's class, collective and purposeful features of DT were partially observed, and others were absent.

Teacher 09

The teacher started the lesson of the day with the previous lesson "uniform motion," and the classroom layout was for group discussion. The teacher has presented concepts to be discussed; this indicates the lesson was purposeful.

The teacher has been asking how and why questions after students' answer to close-ended questions:

Teacher	Is the motion is uniform or not? (Indicating a table shown in Figure 4.5)
Students	Uniform motion (in chorus)
Teacher	How or why? Are the time the same or distance the same?
Students	Displacements in equal time interval are the same.
Teacher	In equal time interval there is equal displacement and also we can see velocities are the same.

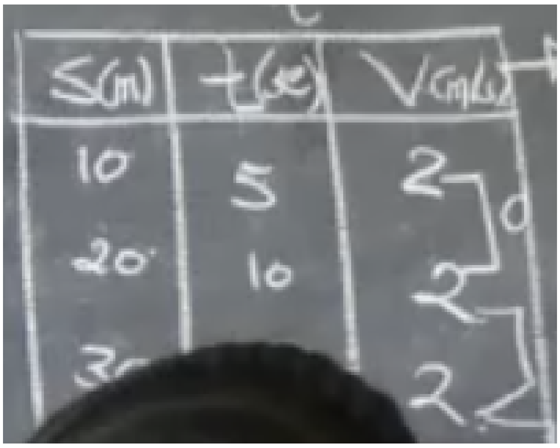


Figure 4.5: Tabular representation of uniform motion

Teachers' question elicit evidences of students understanding and challenge their thinking.

Teacher	What is slope?
Student	Vertical increase over horizontal increase
Teacher	In our case what is vertical increase?
Students	displacement
Teacher	displacement over, x-axis?
Students	time
Teacher	change in distance over change in time (by writing on the board).What is change in distance over change in time?
Student	speed

In the lesson transition phase, the teacher has been using lecture and question and answering methods. The teacher was asking a series of questions based on the student's answers. The questions focus on the topic of the day.

At the end of the class, the teacher has to give exercises in the worksheet problem, which students will submit in the next class. The questions were clear and challenged students' understanding. In the class, the students respected their peers' point of view by listening to each other attentively. Therefore, the class was collective, reciprocal, cumulative, supportive, and fully purposeful.

As indicated in Table 4.3, Table 4.4 and Figure 4.6: collective feature of DT was partially demonstrated in six teachers' class and did not demonstrate in three teachers' classes; Reciprocal feature of DT was partially demonstrated in two teachers' class and did not demonstrate in seven teachers' classes; Supportive feature of DT was partially demonstrated in three teachers' class and did not demonstrate in six teachers' classes; Cumulative feature of DT was partially demonstrated in four teachers' class and did not demonstrate in five teachers' classes, and three teachers' class fully demonstrated purposeful feature of DT, partially demonstrated in five teachers' class and did not demonstrate in one teacher's classes. Only the purposeful feature of DT is demonstrated fully.

Table 4.3: Summary of DT in teachers' classes

		Features of Dialogic Teaching					
Teacher	Trained	Collective	Reciprocal	Supportive	Cumulative	Purposeful	Average
01	yes	2.0	2.0	2.0	2.0	3.0	2.2
02	yes	2.0	1.0	1.0	1.0	2.0	1.4
03	yes	1.0	1.0	1.0	2.0	3.0	1.6
09	yes	2.0	2.0	2.0	2.0	3.0	2.2
04	no	2.0	1.0	1.0	1.0	2.0	1.4
05	no	2.0	1.0	1.0	2.0	2.0	1.6
06	no	1.0	1.0	1.0	1.0	2.0	1.2
07	no	1.0	1.0	1.0	1.0	1.0	1.0
08	no	2.0	1.0	1.0	1.0	2.0	1.4
Average		1.7	1.2	1.2	1.4	2.2	1.6

Note: 1.0 = no, 2.0 = partial, and 3.0 = Full

The reciprocal and supportive features were the most difficult to demonstrate in teachers' class, and the purposeful feature was better demonstrated than other features of DT. In general, features of DT were not well-demonstrated in every teacher's class. Relatively, teachers who have training on DT have demonstrated better than those who have no training on DT (This part is more discussed in comparative analysis section 4.6).

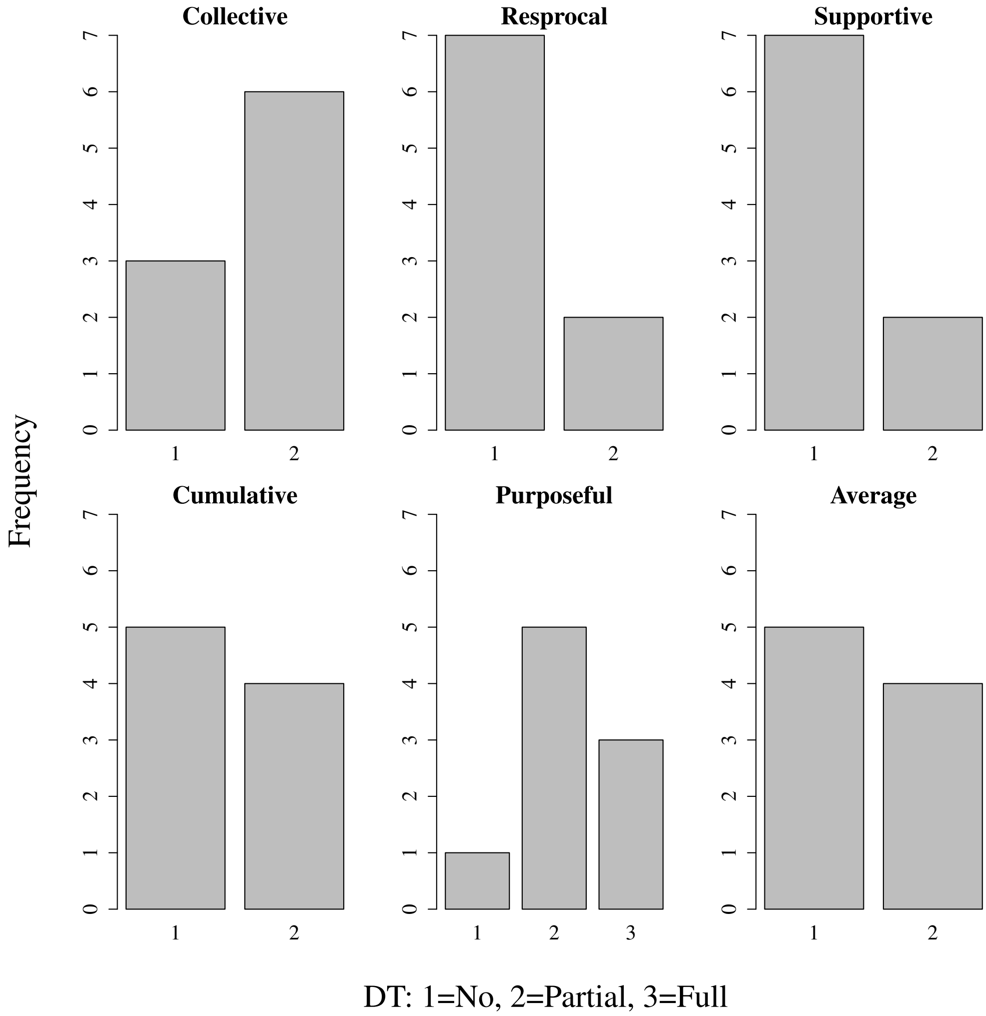


Figure 4.6: Implementation of DT in Physics class

Table 4.4: Frequency table for implementation of DT

	Features of DT					
Impleme.	Collective	Reciprocal	Supportive	Cumulative	Purposeful	Average
No	3	7	7	5	1	5
Partial	6	2	2	4	5	4
Full	0	0	0	0	3	0

4.3 Analysis of Teachers' Content Knowledge

4.3.1 Introduction

In this section, the SCPS teachers' content knowledge on *Newton's law of motion,* and *Graphical representation of motion* were analyzed. Instruments used to collect data were classroom observation and questionnaire. Therefore, the analysis was held as: observed in the classroom and confirmed in the questionnaire.

4.3.2 Teachers' CK as Observed in Physics Class

Classroom observations were held in the first semester of the 2018-2019 academic year in each teacher's classroom when they were teaching. They were teaching subtopics under Newton's laws of motion in grade 7 or Graphical representation of motion in grade 8. The video-based classroom observations were transcribed and analyzed using NVivo software. Two main categories of teachers' content knowledge (Conceptual and procedural) were considered in this analysis.

Teacher 01

The definition imparted by teacher 01 to the student was consistent with Newton's first law in literature. She raised relevant examples in the class: What we feel when a car starts its motion and stops its motion. The teacher also demonstrated the relationship between mass and inertia: the inertia of a body of large mass is greater than the inertia of small mass. Teacher 01 related inertia with our thinking as "... when we are in a moving car, we think of the motion of the car, and when the car stops its motion, we think of its motion, and this is also the law of inertia."

She demonstrated the direct relation between acceleration and net force applied to the body and the inverse relation between the body's acceleration and mass in her presentation. The teacher did not consider lifting an object as applying force. She said, "Not lifting the mass applies force by pushing or pulling." The teacher conceptualized that lifting mass is not applying force.

In these two classroom observations of Teacher 01, the teacher's limited knowledge of inertia applied force, and procedures in solving Newton's second law's numerical problems were revealed. Hence, the teacher has poor knowledge in both components: conceptual and procedural knowledge.

Teacher 02

The teacher started with a tabular representation of motion and computed velocity and acceleration from the table; then, she started piloting the graphs by marking each coordinate in $s - t$ and $a - t$ planes. These indicate her good procedural knowledge in the plotting graph.From her tabular representation shown in Table 4.5a teacher 02 compute average velocity by dividing each position (displacement) with each corresponding time: $v = \frac{2}{1} = 2$, $v = \frac{4}{2} = 2$, etc, which indicates that the teacher has a misunderstanding of the definition of average velocity, which is the ratio of change in position(displacement) to the time elapsed ($v = \frac{S}{\Delta t}$). The division's result was correct for a motion that starts its motion from zero displacements (position). However, this does not work for a motion that starts from a non-zero initial position. This has limited her conceptual understanding of average velocity and average acceleration.

Table 4.5: Teacher 02's Tabular representation of Motion

(a) Uniform motion

$s(m)$:	2	4	6	8	10
$t(s)$:	1	2,	3	4	5
$v(m/s)$:	2	2	2	2	2

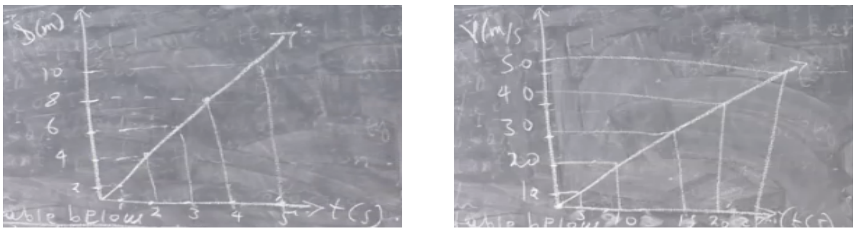
(b) Uniformly accelerated motion

$V(m/s)$:	0	10	20	30	40	50
$t(s)$:	0	5	10	15	20	25
$a(m/s^2)$:	0	2	2	2	2	2

Similarly in finding acceleration of a motion from Table 4.5b, the teacher divided each velocity by each corresponding time: $a = \frac{0}{0} = 0$, $a = \frac{10}{5} = 2$, $a = \frac{20}{10} = 2$, and etc. The teacher has misunderstanding, in definition of average acceleration which is the ratio of change in velocity to total time elapsed ($a = \frac{\Delta v}{\Delta t}$).

During her presentation, the teacher asked what the value of $\frac{0}{0}$ is? The students answered in a chorus, ”zero.” The teacher accepted the students’ answer $\frac{0}{0} = 0$, which indicates that the teacher and the students had a misunderstanding on a number over zero, which is undefined. They were talking about a uniformly accelerated motion, which is about constant acceleration. But the results of their calculation were different: 0 at time $t = 0$ and $2m/s^2$ at other times. These contradict the value of uniformly accelerated motion, which is constant.

Even though they lack neatness and lines were not drawn correctly, the teacher’s $s - t$ graph for uniform motion and $v - t$ time graph for the uniformly accelerated motion were well done, as shown in Figure 4.7. However, the teacher did not plot the $v - t$ graph for uniform motion and $a - t$ graph for uniformly accelerated motion; and did not raise the issue of slope and area under the $v - t$ curve, which was parts of the topic: graphical representation of motion.



(a) S-t graph for UM *(b) V-t graph for UAM*

Figure 4.7: Teacher 02’s Graphical Representation of Motion

The teacher populated the tables with necessary data for both uniform-motion and uniformly-accelerated motions and then sketched the graphs based on the tables. She marked the coordinates in planes and connected the points in both $s - t$-graph and $v - t$ graphs. Then she connected the points with a straight line and stated that this is a $s - t$ graph and this is a $v - t$ graph by pointing to Figure 4.7a and Figure 4.7b respectively. But she did not mention the properties of the graphs such as the slope of the $s - t$ graph and the area under the $v - t$ graph curve, which has physical meanings: velocity and displacement, respectively. Therefore, the teacher has good procedural knowledge in general, whereas her conceptual knowledge was poor in plotting the $v-t$ graph and $a-t$ graph.

Teacher 03

Teacher 03 described the relation between speed and velocity, and distance and displacement when the direction of motion is along a straight line very well (good conceptual knowledge). The teacher demonstrated both tabular representation and a graphical representation of uniform motion. He populated the first and second row of the uniform motion table and calculated the motion's velocity, and populated the row as shown in Table 4.6a (good procedural knowledge). In doing all these, the teacher has shown his knowledge and skill of representing uniform motion in the table.

Table 4.6: Teacher 03's Tabular representation of Motion

(a) Uniform motion

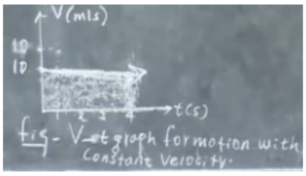
S(m)	10	20	30	40
t(s)	1	2	3	4
V(m/s)	10	10	10	10

(b) Uniformly accelerated motion

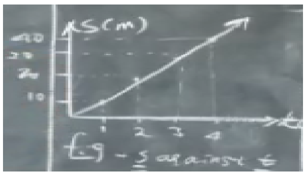
$v(m/s)$	10	20	30	40
$t(s)$	1	2	3	4
$a(m/s^2)$	10	10	10	10

In calculating the velocity, the teacher divided each displacement (position) with each corresponding time. The result was correct, but if the object's initial position was non-zero, the result could not be correct. Here, the teacher forgot that average velocity is the ratio of change in position (displacement) to the time elapsed ($v = \frac{\Delta S}{\Delta t}$) (poor conceptual knowledge).

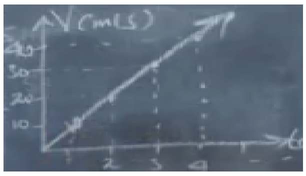
The teacher explained what the vertical and horizontal axes represent. In both $s-t$ and $v-t$ graphs, he has demonstrated very well which variable should be placed on x-axis and which one on the y-axis. After locating the two coordinates t and v, he joined the points by a line and said this is the graph. The graph is shown in Figure 4.8a. The graph was a horizontal line, and the teacher stated that, for uniform motion, the graph is a horizontal line. After plotting a $v-t$ graph, the teacher computed the area under the graph and related to its physical meaning displacement of the motion in that time interval.



(a) V-t graph for UM



(b) S-T graph for UAM



(c) V-t graph for UAM

Figure 4.8: Teacher 03's Graphical representation of Motion

Also, the teacher plotted the $s-t$ graph using the tabular data in Table 4.6a as shown in Figure 4.8b. The teacher demonstrated very well that the graph's slope was the velocity of the motion, which was constant.

The teacher also populated a table for uniformly accelerated motion with the values of velocity, time, and then calculating the value of acceleration in the third column, as shown in Table 4.6b. To find the acceleration of the motion, he divided the value of each velocity in the table with the corresponding value of time. The result was correct, but it does not work if the motion did not start from rest. Here the teacher forgot average acceleration is a change in velocity over total time elapsed $a = \frac{\Delta v}{\Delta t}$.

Using velocity and time values in the table, the teacher demonstrated how to plot a $v-t$ graph in a uniformly accelerated motion. The graph is shown in Figure 4.8c. After plotting the graph, he focused on the properties of the graph: slope. The teacher has related well the slope of the $v-t$ graph with acceleration and area under the curve with distance. From the area under the curve, he derived the equation of displacement for uniformly accelerated motion.

The teacher has gone through the necessary steps in the graphical representation of motion. He has shown what was required in plotting graph: tabular representation of data, coordinate system(x and y axes); substituting x and y axes with variables of motion (displacement, velocity, and time) and; locating the coordinates in planes (v-t plane and s-t plane) and connecting the points in the plane; stating the type of graph plotted and finally explaining the properties of graphs. These necessary steps have been observed in both lessons. Moreover, in this teacher presentation, there was no significant interruption of ideas. The flow of the teacher's idea was smooth and precise. In general, the teacher's procedural knowledge was excellent, and conceptual knowledge was good.

Teacher 04

From his review on the previous lesson, the teacher's conception of Newton's laws of motion and uniform-motion were consistent with the literature. After review of the previous lesson the teacher sketched the $s-t$ graph as shown in Figure 4.9 (Poor pro-

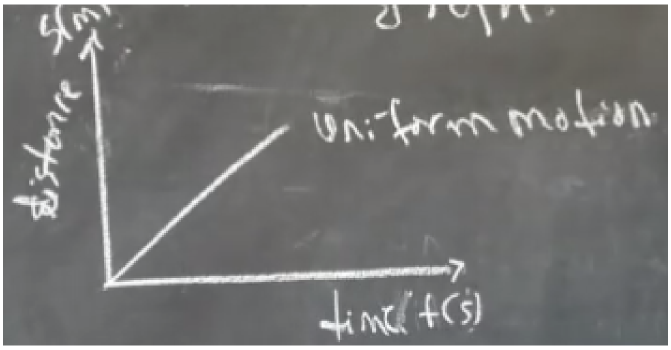


Figure 4.9: Teacher 04's S-t graph for UM

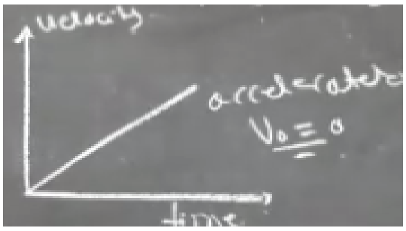
cedural knowledge. It was better if he starts from tabular representation, locating the coordinates then plot the graph). He stated that the $s-t$ graph for uniform motion is a straight line.

Then the teacher draws a uniform motion table and populated the time and displacement rows, and he made the students populate the velocity by calculating from displacement and time rows (Table 4.7).

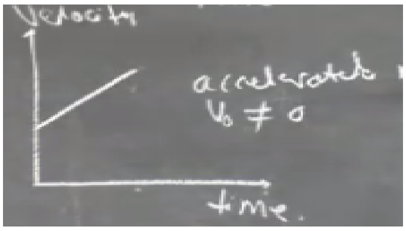
Table 4.7: Teacher 04's Tabular representation of Uniform motion

s(m)	6	12	18	24	30	36	42	48
t(s)	1	2	3	4	5	6	7	8
v(m/s)	6	6	6	6	6	6	6	6

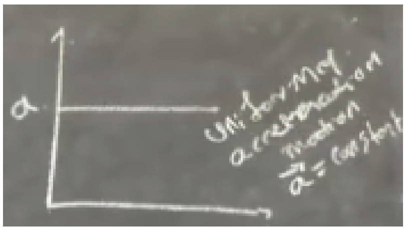
In computing average velocity the students divided distance (position) with corresponding time: $v = \frac{6}{1} = 6$, $v = \frac{12}{2} = 6$, $v = \frac{18}{3} = 6$ and etc. The results were correct. If the initial position or displacement was non-zero, the results were incorrect. Here the



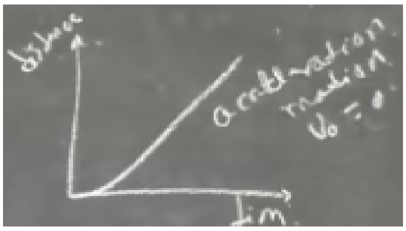
(a) v-t graph for UM



(b) v-t graph for UM



(c) a-t graph for UAM



(d) S-t graph for UAM

Figure 4.10: Teacher 04's Graphical representation of uniformly accelerated motion

teacher and the students forgot the definition of average velocity, $v = \frac{S}{\Delta t}$. After plotting the $s - t$ graph, the teacher did not explain the graph's properties to the student and did not plot the $v - t$ graph (poor conceptual knowledge of average velocity).

Teacher 04 sketched $v - t$, $a - t$ and $s - t$ graphs for uniformly accelerated motion without using any tabular representation as shown in Figure 4.10d (poor procedural knowledge).

The teacher derived the equation of motion for uniformly accelerated motion arithmetically, as shown in Figure 4.11. From the teacher's derivation, it is easy to say the teacher has a good conceptual understanding of uniformly accelerated motion. But this derivation was beyond the student's level. At this level, it was better if the teacher used properties of the $v - t$ graph such as slope and area under the curve to compute acceleration and displacement, respectively. Even though the steps in driving equations of motion were good, at this level, it is not recommended; it is better to use slope and area under the curve to compute velocity and displacement, respectively. Therefore, the teacher's procedural knowledge was poor.

The teacher asked the students to plot the $s - t$ graph from tabular data, and the way the students drew the graphs were wrong. When students draw the graph, they draw a straight line that passes through the origin and then connected the displacement and

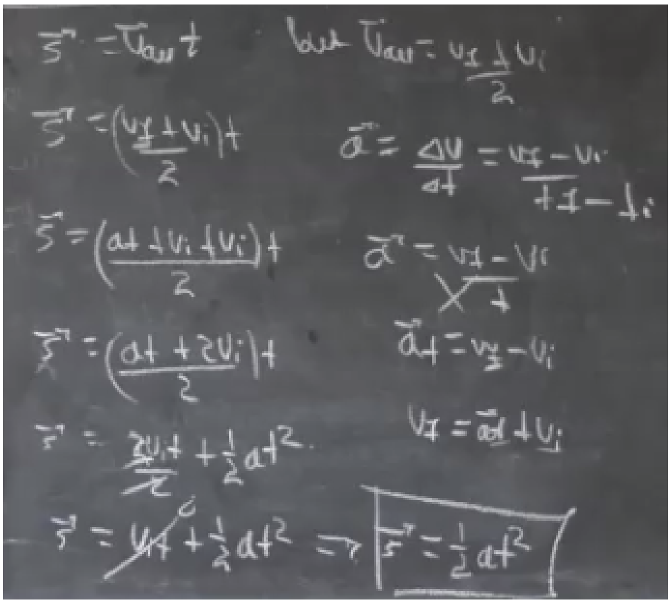
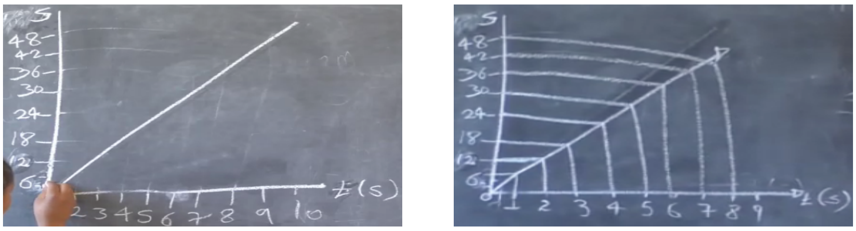


Figure 4.11: Teacher 04's steps in deriving displacement in UAM

time values, as shown in Figure 4.12a and Figure 4.12b. Tabular data were not used in plotting the graph. The teacher accepted the students' works with awards by saying "very good," and he did not comment on the wrong procedure they had gone through, which indicates that the teacher's procedural knowledge of the $s-t$ graph was limited. In general, the teachers' conceptual and procedural knowledge was poor.



(a) *(b)*

Figure 4.12: Teacher 04 students' S-t graph for UM

Teacher 05

When teacher 05 asked the class to define Newton's second law, every student's definitions of Newton's first law of motion was incomplete, and the teacher accepted students' answers whether they were correct or not. The teacher did not amend the students' answers. When she summarizes her lesson on Newton's first law of motion, the definition imparted was incomplete. "Newt Newton's first law of motion state that an object at rest remains at rest, an object in motion continues at a constant speed or velocity in a straight line." These indicate that the teacher may have no concrete understanding of Newton's first law of motion (poor conceptual knowledge).

In her notes, the teacher mentioned the properties of action and reaction forces very well and demonstrated the existence of the two forces in a pair: action and reaction, by pushing at the wall and making two students push each other. In the second demonstration, the teacher ordered two students to push each other with equal force. That means the students can push each other with unequal force. She means that if two objects exert forces on each other and one accelerates the other, it exerts greater force than the one which is accelerated. Therefore, the teacher has a misunderstanding in Newton's first law (poor conceptual knowledge).

The teacher has explained Newton's second as: acceleration of a body is proportional to the force applied and inversely proportional to mass (she read the board). She derived, by crisscrossing equation for acceleration and mass, the force equation. She explained what the direct proportionality between force and acceleration is. $\vec{a}$ is proportional to $\vec{F}$, which means that if the acceleration increases, the force also increases, and if the force decreases, the acceleration decreases. Acceleration is inversely proportional to mass. If the mass increases, the acceleration decreases, and if the mass decreases, the acceleration increases (demonstrated good conceptual knowledge).

In solving problems on Newton's second law of motion, she wrote the problems clearly on the blackboard. She started solving the problem by identifying the givens and what was required and then solving the problem using appropriate equations and clear steps, which indicates the teacher has good procedural knowledge in problem-solving.

Teacher 06

From her review of the previous lesson, the teacher conceptualized the three of Newton's laws of motion as the types of motion. The teacher demonstrated well how Newton is related to $kg \times m/s^2$ (good procedural knowledge), and defined weight is the pull of the earth. Moreover, the teacher asked what the force or the pull of the earth is. The students responded $9.8 m/s^2$, and the teacher accepted the answer and repeated

$9.8m/s^2$, which indicates that the student and the teacher conceptualized gravitational acceleration as the object's gravitational force or weight. This conception was different from what the teacher wrote in her note. In her notes, gravity is considered as if it is a force, and in her explanations, gravity is considered as an acceleration (poor conceptual knowledge). In literature, gravity is a force (attraction of two bodies because of their mass) with SI unit N. In contrast, gravitational acceleration is an acceleration due to gravity (gravitational acceleration) with SI unit m/s^2 (poor procedural knowledge).

The teacher explained very well the existence of the two forces: action and reaction forces, by considering a ball that we hit with our toes. The force that we exert at the ball is the same, and opposite to the ball's force exerts on our toes. She also used another example, holding a book and sketching a diagram for the book, as shown in Figure 4.13. However, the explanation given to the relation between action and reaction forces were confusing. The teacher stated that "...action is equal to the negative of reaction. The reaction-force for the action-force is positive. The sign indicates that the reaction force is positive to action force." According to the literature, the two forces (action and reaction forces) are negative to each other. If the reaction force is positive to the action force, the action force is also negative to the reaction force. In Figure 4.13, for example, the upward force is negative to the downward force, and the downward force is negative to the upward force (poor procedural knowledge).

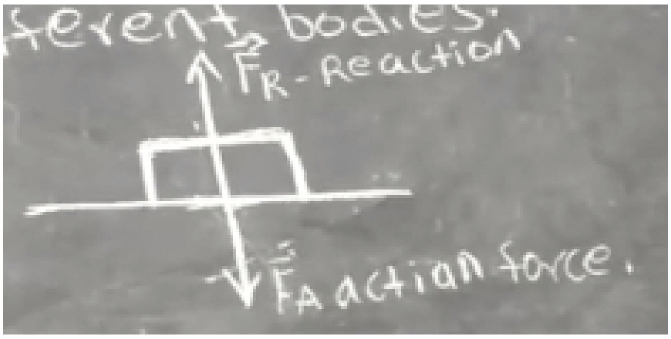


Figure 4.13: Action and reaction forces

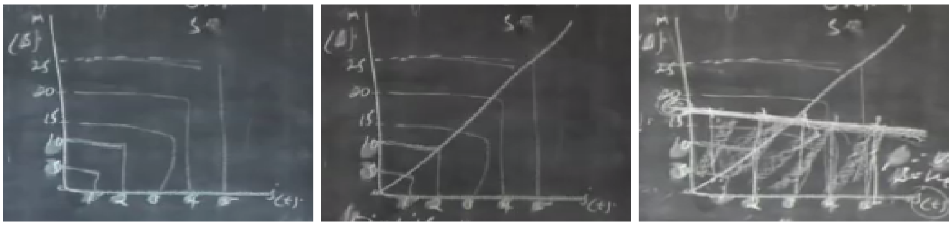
A student asked the teacher why we do not use one arrow for action and reaction forces? The teachers answered that both are vectors, which should not be the answer to the question raised. Right the two arrows represent vectors, but the two arrows are used to indicate two objects exerting two different forces on each other, which are directed up and down. Another student asked, can't we have more than two forces in action and reaction? However, the teacher did not answer the question. The teacher and the students' conversation was in Amharic in order to not hinder their communication. Therefore, the teacher could not answer the question because of her poor CK of Newton's third law of motion.

In demonstrating Newton's third law of motion, the teacher asked two students to push each other with equal forces. The teacher had a conception if one student can move/accelerate the second student; he has applied a larger force than the second student. The teacher asked them to push each other with equal forces as if the two students could exert two different magnitudes of forces. This idea contradicts Newton's third law of motion, which states that there is equal and opposite reaction force for every action. Even though one object accelerates another object, the two objects exert the same magnitude forces on each other. In the demonstration, a student asked which force is negative from the two students' forces, but the teacher did not respond, which shows that the teacher has no clear understanding of action and reaction forces. Therefore the teacher has a limited understanding of Newton's third law. Therefore, the teacher has an average conceptual knowledge and poor procedural knowledge.

Teacher 07

Teacher 07 stated that "Free falling body means any object throw the sky come to the earth by gravitational. That gravitational speed 9.8 m/s in the last class." This definition of free fall was inconsistent with the definition in literature, and the teacher has difficulty differentiating gravitational acceleration and speed (poor conception of free fall).

In plotting, $s - t$ graph, the teacher drew horizontal and vertical lines and labeled them s and t, respectively. Each axis was scaled with a consistent interval as shown in Figure 4.14a and Figure 4.14b . In order to find the velocity of motion, which was not given, the teacher divided the displacement scales with a corresponding time scale: $v = \frac{5}{1} = 5$, $v = \frac{10}{2} = 5$, $v = \frac{15}{3} = 5$, etc (this indicates that teachers conception of average velocity was poor). The teacher then connected each coordinate of s with each coordinate of t, then drew a line and stated, this is the $s-t$ graph for uniform motion (poor procedural knowledge of plotting graph). It seems the teacher forgot that average velocity is total displacement divided by total time ($v = \frac{S}{\Delta t}$). The teacher plotted the graph without having the data. Another person may connect values of displacement scales with time scale values in different ways and obtain different velocity. Moreover, the teacher divided 10 by 0 and said the answer was zero. These indicate that the teacher's procedural knowledge of the plotting graph was limited and had misconceptions of dividing a number by zero.

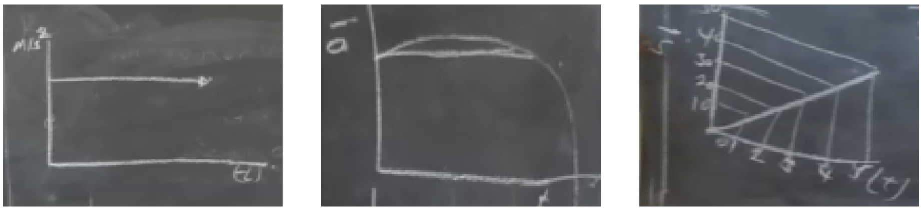


(a) s-t *(b) s-t* *(c) S-t and V-t*

Figure 4.14: Graphical representation of uniform motion

Teacher 07 conceptions of uniform motion were naive. He considers velocity, time, and distance are constant in uniform motion (poor conception). The teacher asked students to plot a $v-t$ graph without giving tabular data or equations, only by scaling the t-axis and v-axis. Finally, when the students could not plot the graph, the teacher connected scales on the vertical axis to scales on the horizontal axis, as shown in Figure 4.14a. The teacher was not confident in his graph. As a result, he was erasing and redrawing the graphs on the blackboard several times. This confusion arises due to the limited knowledge and skills of plotting a graph. Just when he started his presentation, the teacher was overconfident about what he was teaching. However, as time went out, his confidence ebbed.

The teacher has demonstrated plotting an $a-t$ graph of uniformly accelerated motion by sketching graphs as shown in Figure 4.15a and 4.15b. According to him, the $a-t$ graph, shown in the Figure 4.15b is negative, and the motion is uniformly accelerated motion. He explained that if the magnitude of acceleration decreased, then the acceleration is negative (very poor procedural and conceptual knowledge).

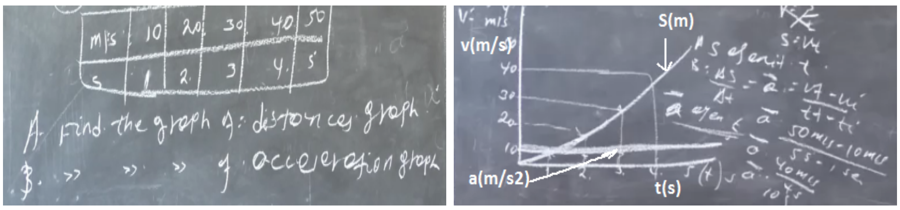


(a) a-t graph for UAM (b) a-t graph for UAM (c) S-t graph for UM

Figure 4.15: Teacher 07's Graphical representation of motion

Teacher 07 stated that in a uniformly accelerated motion, velocity is constant, and speed is varying. "Speed is constant when uniform velocity and speed vary when uniform acceleration." He interpreted the s-t graph shown in Figure 4.15c, the motion is uniformly accelerated, and the initial position and initial velocity are zero at the initial time, $t = 0$. The graph represents uniform motion with the initial position zero and the velocity constant. The teacher did not differentiate uniform motion and uniformly accelerated motion and could not interpret the graph correctly (poor conceptual knowledge).

Tabular data were given to students, as shown in Figure 4.16a. The table has two rows–the first row was velocity and the second one was time. They were labeled by their SI units m/s and s, respectively. These representations were unusual. Most of the time, the names of the physical quantities are used. Based on the data, two questions were asked (poor procedural knowledge).



(a) Tabular representation (b) Graphical representation

Figure 4.16: Teacher 07's Representation of uniformly accelerated motion

The teacher compute each displacement by multiplying each velocity with each corresponding time ($s = vt$): $s = 1 \times 10 = 10$, $s = 2 \times 20 = 40$, $s = 3 \times 30 = 90$ and etc. This approach does not hold for an object that starts its motion from rest and moves with uniformly accelerated motion, which indicates that the teacher has no concrete CK of uniform motion and uniformly accelerated motion. One can compute displacement at any time, for uniformly accelerated motion using an equation, $s = v_0 + \frac{1}{2}at^2$. However, this equation is beyond the level of the students. At this level, it is better to use the area under the $v-t$ graph to compute displacement.

The teacher sketched both $s-t$ and $a-t$ graphs, as shown in Figure 4.16b on the same plane using the values of velocities, which indicates that the teacher has no knowledge and skill of plotting graphs. This teacher has no sufficient content knowledge of Newton's law and graphical representation of motion and has no plotting graph skill. In general, teachers have very poor conceptual and procedural knowledge.

Teacher 08

The teacher conceptualized mass and inertia are the same, and large mass has high inertia than small mass (poor conception). This conception arises from "mass is the measure of inertia." The teacher asked, "A body is at rest when subject to the forces shown in Figure 4.17 find x and y." This example was not that relevant to the topic.

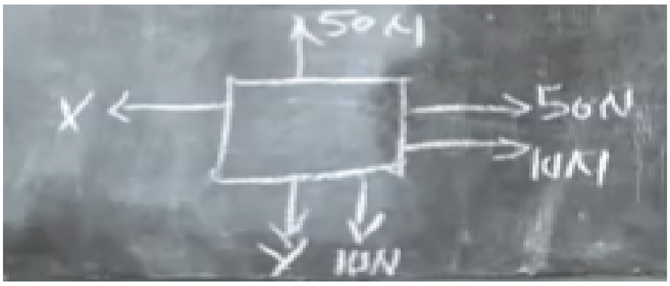


Figure 4.17: Teacher's diagram used as an example of Newton's first law

Moreover, in the computing forces required to keep the block in Figure 4.17, there were no clear steps demonstrated (poor procedural knowledge). The teacher did not demonstrate, using mathematical expression or another technique, to solve unknown forces acting on the block. In general, this teacher has no sufficient content knowledge to teach Newton's first law and second law for the SCPS.

Because of her limited knowledge, the teacher was influenced by students' answers. For example, a student answered a question correctly, but other students said no, and the teacher accepted that the student's answer was wrong. Moreover, the teacher did not comment on students' answers, whether it is correct or not, except awarding "thank you." which shows that the teacher was not confident in her knowledge. A teacher is confident if she/he is knowledgeable of his/her subject matter. The teacher defined Newton's first law of motion as :

> Newton's first law of motion contacts that an object continues each in state of rest or uniform motion along a straight line.

The definition was incomplete and different from what the teacher gave notes on the blackboard. The definition given in the note was:

> an object continuous in its state of rest or of uniform motion unless it is forced to change in straight line the application of an external force.

What the teacher read from her notebook, and she explained verbally about inertia were different. From her explanation, the teacher conceptualized a body at rest has inertia, and a body that moves with a certain velocity has no inertia. The teacher restated that Newton's first law of motion means an object at rest. These all indicate that the teacher's knowledge of force and unit of force was limited, and the teacher conceptualized that only an object moves when there is an external force applied to it. In general, the teacher's conceptual and procedural knowledge was very poor.

Teacher 09

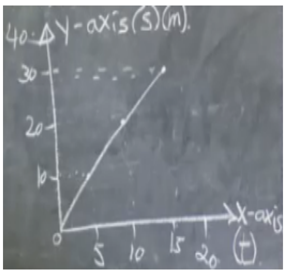
Teacher 09 well-introduced about the graph, using x and y coordinates and then drawing a table with three rows: displacement, time, and velocity, as shown in Table 4.8. The teacher populated displacement and time rows and then computed the velocity (very good procedural and conceptual knowledge). When he compute velocity, the teacher divided each value of displacement with each value of the corresponding time as $v = \frac{10}{5} = 2$, $v = \frac{20}{10} = 2$, etc. (This limited his conceptual knowledge of average velocity and average acceleration). All results were correct, $2m/s$. The result was incorrect if the motion was not uniform motion or the initial displacement was non-zero. The teacher forgot the definition of average velocity, which is total displacement divided by time elapsed ($v = \frac{S}{\Delta t}$).

Table 4.8: Teacher 09's Tabular representation of UM

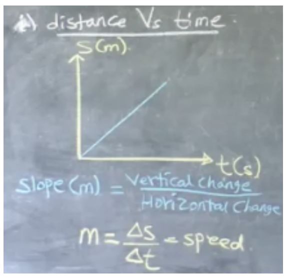
s(m):	10	20	30	40
t(s):	5	10	15	20
v(m/s):	2	2	2	2

The teacher mentioned explicitly what do x and y axes represent in both the $v-t$ graph and $s-t$ graph. After that, he plotted the $s-t$ graph by locating each displacement and time coordinates. Then he drew a straight line by connecting the points as shown in Figure 4.18a and stated that the $s-t$ graph for a uniform motion is a straight line. The graph was clear and neat (very good procedural knowledge).

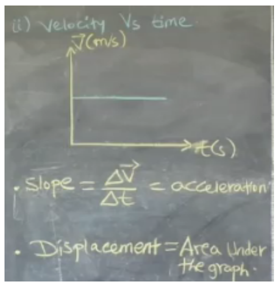
After drawing a $s-t$ graph, the teacher demonstrated the slope of the graph is velocity, as shown in (Figure 4.18b). The teacher stated that the slope of the $s-t$ graph is the velocity of the motion. And sketched $v-t$ graph, as shown in Figure 4.18c. The teacher was knowledgeable about the topic he was teaching (very good conceptual knowledge).



(a) S-t graph



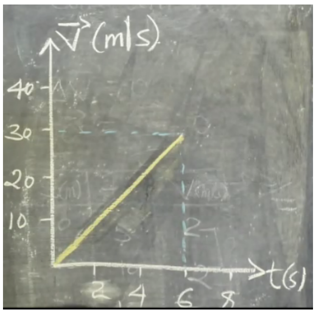
(b) Computing velocity



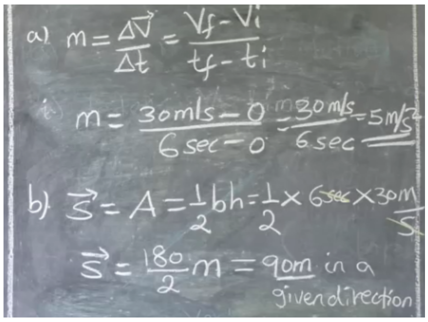
(c) computing distance

Figure 4.18: Graph representation of uniform motion

At the end of his presentation, the teacher gave a problem based on the graph (4.19a). The problem was clear, and the graph was legible, labeled, and scaled and neat. The teacher has demonstrated how to locate points in the graph, such as initial velocity and final values. As shown in Figure 4.19b, steps in solving the numerical problems were very neat and clear. In general, his presentation well-organized, sequential, and enjoyable. Therefore, the teacher's conceptual knowledge was good, and his procedural knowledge was very good.



(a) v-t graph



(b) Steps in solution

Figure 4.19: Teacher 09's Graph and steps

In general, every teacher has misconceptions. The misconceptions vary from teacher to teacher and severe in two teachers (07 and 08). Misconceptions observed in grade 7 physics classes were in inertia, in Newton's laws of motion, average velocity, average acceleration, equation of displacement in uniformly accelerated motion, and gravitational acceleration and force. Two teachers (01 and 08) conceptualized inertia differently from the existing literature. Teacher 01 relates inertia with our thinking, and Teacher 08 stated a body at rest has inertia, and a body that moves with a certain velocity has no inertia.

Grade 7 teachers had different conceptions of Newton's laws of motion: Teacher 08 conceptualized the effects of force as Newton's laws of motion and Teacher 06 conceptualized Newton's laws of motion as three types of motion. For teacher 01, lifting an object is not applying a force. This conception may arise from work done on an object, which is zero when it moves sideways by holding the object up. Teacher 05 definition of Newton's first law of motion was incomplete.

Teacher 05 conceptualized that if two bodies exert forces on each other and one makes the other accelerated, then it exerts greater force than the one which is accelerated. Teacher 06 conceptualized that the action force is negative (opposite) to the reaction force and the reaction force is positive to the action force. These contradict the concept action and reaction forces are opposite to each other.

Also, the teachers had difficulties in presenting their lessons clearly and sequentially. For example, Teacher 01 has given a problem with a solution as a note. After that, she explained it to the students by reading from the blackboard. Also, teacher 08 was not clear in solving the unknown forces that make a block in equilibrium, and there were problems in plotting graphs from tabular data with clear steps.

Misconceptions observed in grade 8 physics classes were in computing average velocity and average acceleration from the tabular representation of motion. In gravity and gravitational acceleration, in the knowledge of plotting graphs, number over zero, and uniform motion.

All grade 8 physics teachers have difficulties computing average velocity and average acceleration from tabular representations of uniform and uniformly accelerated motion. They had misconception in definitions of average velocity $v = \frac{S}{\Delta t}$ and average acceleration, $a = \frac{\Delta v}{\Delta t}$. They divided each position (displacement) with each corresponding time to compute average velocity and compute average acceleration. They divided each velocity with each corresponding time.

Teacher 07 has misconceptions, similar to teacher 06. He conceptualized gravity (weight) as gravitational acceleration and stated the body's gravity is $9.8m/s^2$. Also, he has a misconception of dividing a number by zero. He conceptualized the number over zero as zero. This teacher has no skill of plotting graphs in motion and interpreting graphs.

Teacher 04 has limited knowledge of interpreting graphs. He used an analytical method rather than using the property of a $v-t$ graph for uniform and uniformly accelerated motion to compute displacement.

Also, there were teachers' difficulties observed in presenting their lesson. There were teachers: who were plotting graphs without having data or equation, only by scaling the vertical and horizontal axes; who plot graph without locating the point of the coordinates; who were plotting graphs first and locate the coordinates; and who were not able to interpret graphs. Summary of each teachers' conceptual and procedural knowledge is given in Table 4.9 and Figure 4.20

Table 4.9: Conceptual and procedural Knowledge

			Content Knowledge		
Teacher	Trained	Service year	Conceptual	Procedural	Average
01	Yes	6	1.0	1.0	1.0
02	Yes	3	1.0	3.0	2.0
03	Yes	4	3.0	4.0	3.5
04	No	8	1.0	1.0	1.0
05	No	6	3.0	3.0	3.0
06	No	11	2.0	1.0	1.5
07	No	3	0.0	0.0	0.0
08	No	10	0.0	0.0	0.0
09	Yes	12	3.0	4.0	3.5
		Average	1.6	1.9	1.9

Note: 0 = very poor, 1 = poor, 2 = average, 3 = good, 4 = very good

As shown in the table and the graph, SCPS physics teachers' conceptual and procedural knowledge on Newtons' law of motion and graphical representation of motion vary from very poor to very good. Two teachers (07 and 08) were very poor in both components. These confirm that teachers' experience has no role in their CK, and implies that teacher education policy should emphasize on the quality of teacher and teacher education emphasize teachers' content knowledge during their training.

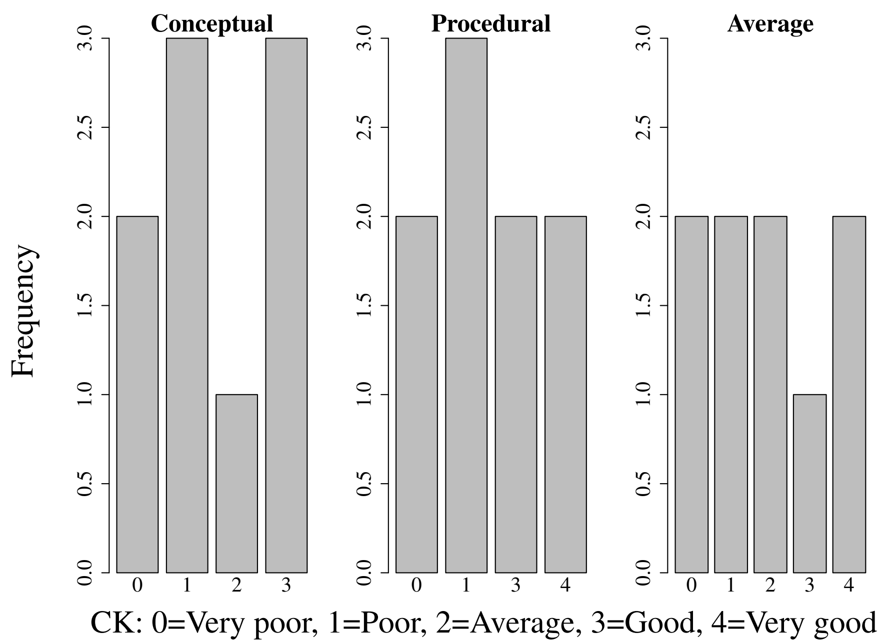


Figure 4.20: Content Knowledge as observed in Classes

4.3.3 Teachers' CK as Manifested in Questionnaire

As shown in Appendix C, the teacher's questionnaire has two parts. The first part has ten items, and each item has three sub-items. Sub item, "a," asks about teachers' content knowledge. The sub-items focus on two topics, Newton's laws of motion and graphical representation of motion. These two topics are there in both grade 7 and 8 curricula. The items start with an open-ended question and then ask for an explanation. The items' main objectives were not to get an answer for the close-ended question, but to probe the understanding and misconceptions held by the teachers. Sub-items "b" and "c" were intended to reveal the pedagogical content knowledge and items 11-22 to reveal teachers' PK.

According to responses to item 1a (Appendix C), six teachers (01, 03, 04 ,05 06 and 09) responses were correct, two teachers (02 and 07) responses were wrong and one teacher (08) did not respond. From their explanation to their answer, according to the existing literature, three teachers (05, 07 and 08) had misconception which is consistent with the Aristotelian conception of force and motion (Crowell, 2001) and five teachers (01, 02, 03, 04 and 06) had correct conceptions of motion of a body and force which is consistent with Newtonian (Crowell, 2001).

Six teachers conceptualized that a body does not stop its motion because of a lack of action force to keep the object moving. The other four teachers conceptualized: an object stops its motion due to inertia (05); if there is no force applied on an object, the object does not move (07); something can move a certain distance depending on the force applied, and gravitational force helps the object to stop, and the force applied decrease as the object goes a certain distance (08); an object stops its motion if the net force applied on it is zero (09).

According to responses to item 2a (Appendix C), three teachers (03, 05, and 09) responded were correct, five teachers (01, 02, 04, 06 and 07) responded were wrong and teacher (08) did not respond. From teachers (03, 05, and 09) explanations, they have conceptualized a difference between $v-t$ graphs for uniform and uniformly accelerated motions. In uniform motion, the graph is a horizontal line with a zero slope. The graph is a straight line with a zero slope in uniformly accelerated motion, which is consistent with literature (Crowell, 2001). From their explanations, fife teachers (01, 02, 04, 07, and 08) assume that in both uniform motion and uniformly accelerated motion, $v-t$ graphs are the same, which is inconsistent with Newtonian mechanics (Crowell, 2001; Serway & Vuille, 2014).

The teachers argue: the $v-t$ graph is constant in uniformly accelerated motion and uniform motion (01); $v-t$ graphs of uniform motion and uniformly accelerated motion are straight lines (02); in both uniform motion and uniformly accelerated motion, the motion is along a straight line, as a result, their $v-t$ graphs are also the same (04); in constant velocity or acceleration, always the motion should be horizontal or parallel on the graph, and uniform motion and uniformly accelerated motion have the same graph which is horizontal to the time axis (07); both uniform motion and uniformly accelerated motion are the same (08).

According to responses to item 3a (Appendix C), no teacher had an understanding of why the Earth does not accelerate toward a mass around the Earth's surface while the Earth and the mass exert the same magnitude of forces on each other. Moreover, two teachers (01 and 02) had misconceptions concerning Newton's third law of motion.

Teacher 01 conceptualized that mass around the Earth accelerated toward the Earth because the Earth's force is greater than the force of the mass because of the magnetic force of the Earth. Teacher 02 argues that Newton's third law does not work for the Earth because the Earth's gravitational force on the mass is greater than the gravitational force of the mass on the Earth.

In responses to item 4a (Appendix C), except teacher 03 all teachers' responses were incorrect. The teachers have conceptualized the relation between velocity and acceleration wrongly. They conceptualized acceleration as proportional to velocity as a result; when velocity increases, acceleration increases, and when velocity decreases, acceleration decreases, which is similar to the Aristotelian conception of force and velocity, which argues $F = ma$ (Crowell, 2001). However, the relation between velocity and acceleration is the time rate of change of velocity. Teacher 03 conception was consistent with the literature. He said, "if the velocity changes with an equal interval, acceleration [does] not change. Acceleration is the time rate of change of velocity."

Except teachers 02 and 08, teachers' responses to item 5a were correct and provided the same reason, which was consistent with the Newtonian conception of force: action and reaction forces act on a different object. The two teachers whose responses were wrong did not state that the two forces act on different objects or the same objects.

All teachers respond to item 6a (Appendix C) correctly. From their explanation, the teachers have the right conception weight of an object on the Earth, and the moon is different because of the gravitational force. The gravitational force of the Earth is greater than the gravitational force of the moon.

According to responses to item 7a (Appendix C), all teachers' responses were wrong. Seven teachers (01, 03, 04, 05, 06, 08, and 09) respond 0, and two teachers (02 and 07) respond undefined. The misconception observed in teachers' responses were two-fold. The first one was in computing average velocity. They divided each distance (position) by each corresponding time. Average velocity is the ratio of the change in velocity to the change in time. The second fold was the misconception of dividing a number by zero, which is undefined. Except for teachers 02 and 07, every teacher conceptualized that number divided by zero is zero.

Only teacher 01's response to item 8a (Appendix C) was correct, which is $4.2m/s^2$. Teachers' explanations, except for teachers (01 and 09), have misconceptions/difficulty in computing average velocity from a graph. They compute average velocity by computing the average velocities at different times: $v = \frac{v_1+v_2+v3+..v_N}{N}$. Others have difficulties in finding displacement from the graph. One teacher said displacement is not given. Others divide a velocity in the graph with the corresponding time.

According to responses to item 9a (Appendix C), responses of three teachers (01, 03 and 08) were wrong. Others responded correctly, and their conception of computing acceleration from the $v-t$ graph was consistent with existing literature. The three teachers (01, 03 and 08) conception of computing acceleration from a graph were different: Teacher 01 conceptualized in the $v-t$ graph that acceleration is constant; Teacher 03 assumed that acceleration for the $v-t$ graph given is not constant. This teacher conceptualized that if the $v-t$ graph of motion is a straight line, then the motion is non-uniformly accelerated motion; Teacher 08 said all of them were incorrect and computed displacement of the motion rather than computing acceleration. In computing displacement, she used an equation $s = vt$. This equation does not work for uniformly accelerated motion, which is given in the graph. So from her explanation, she has difficulty in both computing acceleration and displacement from the $v-t$ graph.

According to responses to item 10a (Appendix C), responses of three teachers (03, 06, and 09) were correct. They responded that the idea was incorrect, and their conception was that the velocity could be in a different direction of force applied, which were consistent with Newtonian mechanics. As an example, teacher 09 raises an object thrown vertically upward, which changes its velocity while both acceleration and force are constant. Responses of six teachers (01,02, 04,05, 07, and 08) were wrong. They responded that the idea was correct, and their conceptions were that acceleration is proportional to force applied on the object, and velocity is directly proportional to acceleration. Therefore, the velocity and acceleration of an object are in the same direction as the force applied, consistent with Aristotelian.

In general, teachers' responses revealed that teachers had numerous misconceptions in grade 7 and 8 physics topics: Newton's law of motion and graphical representation of motion. Some teachers' misconceptions were severe. Teacher 05, 07, and 08 conceptualized that inertia is the cause for a body to stop its motion. If there is no net force applied to a body, it stops its motion, which indicates that these teachers had no clear understanding of Newton's first law of motion and inertia.

All teachers except teacher 03 conceptualized that if the acceleration of a body is proportional to the net force applied, the body's velocity is also proportional to the acceleration of the body. As a result, they argue that if velocity changes, the acceleration of the body changes, and the direction of velocity in the same direction of the net force is applied. This misconception arises from a misunderstanding of acceleration, which says acceleration is the time rate of change of velocity ($a = \frac{\Delta v}{\Delta t}$).

Teachers 01 and 02 were with misconceptions about Newton's third law of motion. Teacher 02 argues that Newton's third law of motion does not work for gravitational force. Teacher 01 argues that because of the Earth's magnetic force, the gravitational force on an object around the Earth's surface and the gravitational force of an object around the Earth's surface on the Earth are not equal in magnitude. Every teacher had no understanding why the Earth does not accelerate toward an object around the Earth, while the objects accelerate toward the Earth.

All teachers have misconceptions about average velocity. To compute average velocity from the tabular representation of motion, they divided each displacement with each corresponding time in the table. Except for teachers (02, and 07), all teachers have misconceptions in dividing numbers by zero. They responded that a number divided by zero is zero. Except for teachers 01 and 09, all teachers have no skill in interpreting $v-t$ graphs. Teacher 01. 03 and 08 could not compute acceleration, average velocity, and displacement from $v-t$ graphs.

As shown in Table 4.10 and Table 4.11, from 10 questionnaires for content knowledge, 9 questionnaires starts with a close-ended question. From these nine questions, the teachers answered $14-67$ % correct. The teachers have misconceptions/difficulties

Table 4.10: Summary of teachers response to content knowledge questionnaire

		Trained Teacher				Untrained Teacher					Total
		01	02	03	09	04	05	06	07	08	
Service year		6	3	4	12	8	6	11	3	10	
Item 1A	Correct	Y	N	Y	Y	Y	Y	Y	N		6
	Misco.	N	N	N	N	N	Y	N	Y	Y	3
Item 2A	Correct	N	N	Y	Y	N	Y	N	N		3
	Misco.	Y	Y	N	N	Y	N	Y	Y	Y	6
Item 3A	Correct	Open-ended question									
	Misco.	Y	Y	N	N	N	N	N	N	N	2
Item 4A	Correct	N	N	Y	N	N	N	N	N	N	1
	Misco.	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Item 5A	Correct	Y	N	Y	Y	Y	Y	Y	Y	N	7
	Misco.	N		N	N	N	N	N	N		0
Item 6A	Correct	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
	Misco.	N	N	N	N	N	N	N	N	N	0
Item 7A	Correct	N	N	N	N	N	N	N	N	N	0
	Misco.	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Item 8A	Correct	Y	N	N	N	N	N	N	N	N	1
	Misco.	N	Y	Y	N	Y	Y	Y	Y	Y	7
Item 9A	Correct	N	Y	N	Y	Y	Y	Y	Y	N	6
	Misco.	Y	N	Y	Y	Y	N	Y	N	Y	6
Item 10A	Correct	N	N	Y	Y	N	N	Y	N	N	3
	Misco.	Y	Y	N	N	Y	Y	N	Y	Y	6
Total	Correct	4	2	6	6	4	5	5	3	1	
	Misco.	6	6	3	3	6	5	5	6	7	
Average	Correct	4.5				3.6					
	Misco.	4.5				5.8					

Note: Y stands for Yes and N stands for No

on $30-78$ % of the ten open-ended questions from the explanation the teachers have given. There were teachers (Teacher 05 on item 1A, and Teacher 04 and 06 on item 9A), who have got the correct answer for the close-ended questions. However, they have misconceptions in their explanation, which indicates that achieving does not mean having the right conception.

Table 4.11: Content knowledge and misconception manifested in questionnaire

	Content Knowledge						Total	Misconception					Total
Trained	1	2	3	4	5	6		3	5	6	6	7	
No	1	0	1	1	2	0	5	0	2	2	0	1	5
Yes	0	1	0	1	0	2	4	2	0	1	1	0	4
Total	1	1	1	2	2	2	9	2	2	3	1	1	9

Teachers who have training on DT have answered correct answers than untrained, and trained teachers' misconception was 47%. Untrained teachers' misconception was 55%, which indicates that the training impacts teachers' content knowledge. The maximum achiever was from a trained group, and the list achiever was from an untrained group. This result is consistent with the analysis held in subsection 4.3.2, on classroom observation.

4.3.4 Summary

Data from the two instruments were consistent. The physics teachers have misconceptions in Newton's laws of motion and graphical representation of motion. The misconceptions were similar to college and high school students (Thijs, 1992; Thornton & Sokoloff, 1998; Clement, 1982), which were consistent with Aristotelian mechanics.

Some teachers have no procedural knowledge in teaching Newton's law of motion and graphical representation of motion. Steps in solving problems were not well-organized and in representing motion in a graph. The steps they followed were not clear, and they could not clearly show how to interpret graphs to its physical mining.

Teachers who were poor in their CK in their class were also poor in response to the questionnaire. The two teachers (07 and 08) have severed content knowledge in both instruments.

4.4 Analysis of Teachers' Pedagogical Knowledge

4.4.1 Introduction

In this section, the SCPS physics teachers' general pedagogical Knowledge on *Newton's law of motion* and *Graphical representation of motion* were analyzed. Instruments used to collect data were classroom observation, questionnaire, and teachers' interviews.

4.4.2 Teachers' PK as Observed in Physics Class

In this subsection, teachers' enactment on Pedagogic Knowledge was analyzed. Therefore, three components of teachers' pedagogical Knowledge: Knowledge of classroom management, Knowledge of teaching methods, and Knowledge of classroom assessment were analyzed.

4.4.2.1 Knowledge of classroom Management

Even though the observed classrooms were the same in dimension, classroom size varies from 27 to 60 students per classroom. Large class size has an impact on classroom management. Weinstein (1979) found that students' density within the classroom affected the frequency of their misbehavior. In less dense classrooms, there is more space per student. Students were more attentive, less distracted, and less aggressive in classrooms with lower density (Garrett, 2014). The classrooms are on the third floor of the buildings or above, helping students not be distracted from windows overlooking. However, at the beginning of the first period, students who were moving in the corridor were destructing students and teachers easily when students returned from break. All classrooms were well-lit and had a blackboard. The classrooms were not decorated with any teaching aid and classroom rules, which implies that teachers did not emphasize teaching aids and classroom rules. This lack of classroom rules is reflected in class during classroom observations. Some students come to the class after 15 minutes. Students answer questions in the chorus and misbehave by saying "me teacher," talking with peers and horseplay in the class, and combing their hair (For example, in teacher 08's class in which the number of students was 60). In every classroom, there was no teacher's table and chair. Some times a teacher can correct/comment students' exercise seating in the class. Teachers need to sit and observe students' activities from a far distance when students start group discussion or individual problem-solving.

The seating arrangement affects teacher's communication, with students' and students' interaction, and students' attitudes and behavior. Every seating arrangement has its merit and its drawbacks. For example, for independent work, the traditional row is better than the cluster seating arrangement (Garrett, 2014). Seating arrangements observed were U-shaped and a group of three or two. In a U-shaped seating arrangement, students sit face-to-face, and they can see each other. This seating arrangement is recommended for group discussions in which students build their knowledge together. In a group of three or two seating arrangements, all students face toward the teacher, which is different from the traditional one, which is fixed and consists of rows, and only one student sits at one desk. However, in three or two groups, students sit on the same desk, and the students face toward the teacher or blackboard. This arrangement is used for the lecture method, and three or two students can also do activities together.

In some classrooms, students were answering questions in a chorus. There was no class attendance held by every teacher. These indicate that there are no classroom rules and routines developed. Students should answer questions by raising their hands, and turns should be kept. To be sure, on students' understanding, the teacher should ask a student a question randomly, probing questions such as how? Why?

According to the grades 7 and 8 Physics syllabus for Addis Ababa city administration (Ministry of Education (MoE), 2009b), the medium of instruction is in the English language. However, as observed in physics teachers' classes, both English and the Amharic languages were used. Teacher 07 has been using the English language most of the time in his class. Every teacher's statement did not have meaning because of the word he was using and his statement construction. Most of the time, the words he was using were not relevant to what he was teaching. His statements were incomplete; rather, they were phrases. For example, when he explained about the graph and uniform motion, he stated:

- In the large of y-direction when is right down y-direction is distance acceleration and velocity right down everywhere.
- In uniform motion speed is constant. Why not, uniform means one. The first definition of uniform means always students wearing by what? uniform, in the same to the uniform. Is not one student change to another student. In similar wearing is uniform.

This teacher could not teach effectively, even if he had good CK. Such a disaster arises due to the lack of CK and the poor language of the teacher.

Other teachers have been using the Amharic language more frequently than English. Also, they translate what they speak in English into Amharic. Some translated the Amharic version, but there was never much with the English version. Except for three teachers (03, 04, and 09), the teachers have severe difficulties explaining their idea in the English language. Teacher 03 and 09 speak concise and clear English, which is good evidence that language ability affected teachers' teaching effectiveness. If the teacher's medium of instruction does not convey the students' real meaning or ambiguity, it leads to poor classroom management. If students could not understand what a teacher says, it results in students to misbehave. Positive usage of language had a significant impact on classroom management, and negative communications harm classroom management.

Students' engagement requires planning and follow-up of the teacher. A teacher should know questions to be raised during group discussion. Probing questions should be structured and well planned. The best questions are ones that are neither too narrow nor too broad. Lively discussions occur when students are asked focused questions with more than one potential answer. Unplanned group discussion is boring, which was observed during the group discussions of some teachers, such as teacher 08. If students are bored, they are liable to sleep, and instead of participating in group discussions, they prepare to leave the class for a break or go home. During group discussion, students should be free to talk. Students share their idea and build their knowledge if they feel free of any harassment. There were teachers (01, 02) who needed the class to be silent during group discussion. Calling students by their name motivates them to be engaged in activities. Teacher 08 was the only teacher who called students by name.

There is a risk in every student's activity in class. Students will not take risks if they do not feel safe and cared for by their teacher and their classmates (Garrett, 2014). Some teachers discourage students when students answer questions (for example, 01, 06, and 07). Students were not treated politely when their answers were out of the topic or when they were wrong. When students' answers were out of the topic, the teacher should respect their answer, make them finish their idea without interrupting, and be awarded for their participation and comment on their answers. When their teacher entered the classroom, students stood up until the teacher ordered them to sit down, which is good concerning Ethiopian culture, which promotes respecting one another. However, if the teachers are forcing the students to stand up, it leads the teacher to autocratic behavior.

Students should have the right to move or stand up at any time without destructing the class. Maybe they have been sitting for a long time. Their movement or standing up should not be restricted only to when the teacher enters the class.

Most teachers' (01, 05, 02, 06, 03, 07) ideas were extremely redundant, and they write notes on the blackboard. They repeat the same idea several times, which has been done in both English and Amharic languages. Repeating the same idea whenever needed is recommended when students ask, or a teacher feels the students did not understand the idea. However, repeating the same idea several times without any reason makes students bored and/or leads toward a shortage of time to cover what the teacher intended to cover. If there were no textbooks for the students, giving a short note is recommended. However, some teachers' notes were a copy of the student's textbook, and the teachers wrote it on the blackboard for a long time (teacher 06, 08, 02). Even it seems that writing a note is the teachers' main activity, and the teachers waste half of their time on writing notes. Teacher 04 was speaking to the blackboard while writing notes and deriving equations on the blackboard, which seems right to save time, but students could not follow what the teacher says. The students mainly concentrated on taking notes. The same was observed in teacher 08's class.

In general, relatively, two teachers (03 and 09) were excellent, four teachers (01, 04, and 05) were average, and three teachers (02, 06, 07, and 08) were weak in their classroom management.

4.4.2.2 Knowledge of Teaching methods

Lecture, question and answering, demonstration, group discussion, and problem-solving methods have been used in teachers' classes. Most teachers have been using the lecture method more frequently than others. The teacher-centered method was used most frequently in all teachers' classes in both groups (trained and untrained). The teachers have been trying to implement these methods in their classes. The problem was how they implemented these methods. Most teachers were not planned for these methods, especially those who have no training inDT.

The teachers have language difficulties in implementing the lecture method in their class. These teachers could not articulate their idea easily in the English language (especially Teachers: 01 02, 07, and 08). Their presentations/lectures were different from their note written on the blackboard. As a result, most teachers have been using Amharic as a medium of instruction. To keep students attentive, the teachers use question-and-answering in the middle of their lectures. The merit of the lecture method depends on teachers' ability to speak in a right style and tone, which requires adequate preparation, which should take into account: objectives of the lesson, a good command of the language, preparation of the materials or lecture, teaching aids, and a good introduction that stimulates students to listen. All teachers did not prepare teaching aids that enhance their lecture (Teachers: 02, 03, 04, 07, and 08). Teachers 03 and 09 have demonstrated a suitable lecture method.

All teachers tried to use the discussion method. However, most of them lack planning for discussion (teachers: 02, 04, 06, o7, and 08). The discussions were in a group or the whole class. There were no well-structured questions distributed or written on the blackboard for group discussion. Questions the teachers were raising were closed-ended and low level.

Similarly, most teachers from both groups did not plan for it in the question and answering method. Two or more questions were asked at a time (02, 07). The teachers raised low-level questions. To address various types of cognitive processes in question, use Bloom's taxonomy (Johnson, n.d.). The teachers did not aim for a direct, specific question. For example, teacher 08 asked what the previous lesson was? Could you explain it? Also, the teachers did not ask open-ended questions. Open-ended questions help students in discussion (Johnson, n.d.).

Similar to other methods, teachers who have been using the demonstration method lack planning. Demonstrations were not tested before classes. For example, teacher 01 tried to show that a large mass has higher inertia than a small mass. However, because of the shapes and the sizes of the objects used, the demonstration failed. A teacher should know what questions should be raised to motivate and direct students' observation and thought before and after the demonstration. When teacher 01 was demonstrating, it was not visible to the students at the back.

In science class, students solve problems. However, what students solve in the classroom is not a real problem rather a mere exercise. Right problem-solving stresses critical thinking and discussion-making skills, whereas the latter requires only applying previous learning procedures. ”True problem solving is the process of applying a method – not known in advance – to a problem that is subject to a specific set of conditions and that the problem solver has not seen before, to obtain a satisfactory solution” Schoenfeld (1980). In these teachers’ classes, problem-solving was applying their previous knowledge to solve a numerical problem or interpret data. Teachers have raised questions in their problems, which are not clear and lack appropriate data to solve the problem. Teacher 07 has been asking students to plot a graph without any tabular data or equation. Problems raised by teacher 04 lacks objectivity. He asked students to solve problems using equations of motion rather than using a graphical representation of motion. Grade 7 and 8 physics syllabus recommend computing displacement of an object performing uniform motion using the area under the velocity-time graph rather than driving equations of motion for uniformly accelerated motion.

In general, the methods chosen by the teacher were appropriate, but most teachers did not implement the methods they had chosen. When we compare the teachers in implementing what they chose, teachers 03 and 09 have implemented excellently. Teacher 01, 04, and 05 were implemented on average, and teachers 02, 06, 07, and 08 were poor.

4.4.2.3 Knowledge of Classroom assessment

There are three primary data gathering methods: student product, observation techniques, and oral questioning techniques Airasian (2001). Even though the degrees were different, the teachers were using three methods. From student’s product, problem-solving/exercise (Teachers 01, 05, 06, 02, 04, 07 and 09), homework (teacher 03), and assignment (teacher 09) were used. Problems/exercises were given in the classes, and the students solved them in a group or individually. After the students solve the problem, they respond to the whole class or show their work on the blackboard. Some teachers did not organize their problems. They lack objectivity and clarity (Teacher 07, 08). Teacher 03 gave homework from students' textbooks and teacher 09 assignments from worksheets prepared by the teacher. Both questions for assignment and homework were clear and to the objective of the lesson.

Even though the extents were different from teacher to teacher, all teachers used observation techniques to collect assessment information. After the teachers have given their students problems, they move among their students and observe students' work and support them. During their presentation and when students respond to questions, the teachers have been observing students' activities. Some teachers were not critical observant of their students' activities and did not respond to misbehaving students (for example, teacher 08).

Every teacher has been using oral questions frequently to assess students' understanding. The questions were used before, during, and after class. Most of the time, the teachers' questions were low level, which did not consider the different levels of Bloom's taxonomy. Some questions were not clear, lack objectivity and specificity (for example, teachers 06, 07, and 08 questions). Some teachers seek other answers even though the correct answer was given without giving any clue to the students (for example, teacher 03 and 09) and probe students understand by asking other questions based on their response. These give chances to other students to share their idea and reveal their misconceptions. On the contrary, most teachers did not accommodate other students' answers once they got the correct answer.

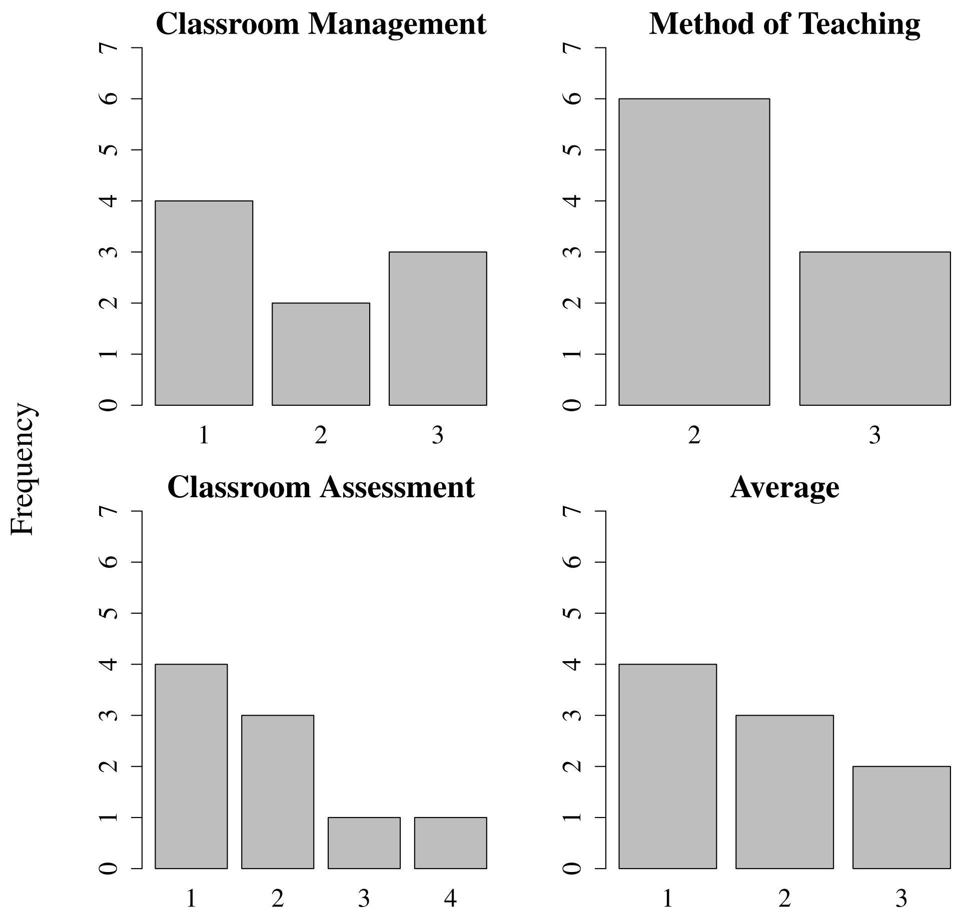
Teachers provide feedback during instruction through their facial expressions, comments, and reactions to questions students ask and responses they provide (Marzano, 2006). In three classroom assessment methods, most teachers have limitations in giving feedback and comment on the students' responses. When students respond, the teachers have been awarding the students without giving them an appropriate comment (teacher 07, 08); if students were incorrect or answered out of topics, instead of appreciating their participation, the teachers discourage them by saying, stop, or you are wrong (teacher 01). How feedback is communicated to students dramatically affects students' achievement (Marzano, 2006). In general, classroom assessments observed in teachers 03 and 09 were excellent and very good respectively; in teacher 01, 04, and 05 were average; and in teacher 02, 06 07 and 08 were poor.

Table 4.12: Pedagogical Knowledge as observed in class

			Pedagogical Knowledge			
Teacher	Trained	Service Year	Classroom Management	Teaching Method	Classroom Assessment	Average
01	Yes	6	2.0	2.0	2.0	2.0
02	Yes	3	1.0	1.0	1.0	1.0
03	Yes	4	3.0	3.0	3.0	3.0
04	No	8	3.0	2.0	2.0	2.3
05	No	6	2.0	2.0	2.0	2.0
06	No	11	1.0	1.0	1.0	1.0
07	No	3	1.0	1.0	1.0	1.0
08	No	10	1.0	1.0	1.0	1.0
09	Yes	12	3.0	3.0	4.0	3.3
		Average	1.9	1.8	1.9	1.9

Note: 0 = very poor, 1 = poor, 2 = average, 3 = good, 4 = very good

Summary of components of teachers' pedagogical knowledge is given in Table 4.12. In every component of teachers' PK 75 % trained teachers have demonstrated greater than or equal to average in their classes, and 40 % un-trained teachers have demonstrated greater than or equal to average in their classes, which indicates that training on DT has an impact on teachers' PK.



PK: 0=very poor, 1=Poor, 2=average, 3=good, 4= very good

Figure 4.21: Pedagogical Knowledge observed in Class

4.4.3 Teachers' PK as manifested in Questionnaire

Item 11-22 (Appendix C) were developed to explore teachers' pedagogical knowledge. Item 12, 15, 17, 18 and 19 were intended explore teachers' understanding and beliefs of classroom management; Items 14, 16 and 20 were intended to explore teachers' understanding; and beliefs of teaching methods and Items 11, 13, 21 and 22 were intended to explore teachers' understanding and beliefs of classroom assessment.

Teachers' responses to item 12 were different. They argue motivating students, makes students active (01), avoid students' shininess (04), encourage students for participation (04, 05, 07), create a sprite of computation (06), enhance students' knowledge (08) and make students mind on and hands-on. Moreover, the teachers argue that students are motivated by demonstration (01), by examples and exercise related to the topic (02, 04), ”by asking energetic question” (03), by awarding students for their activities (08), and by telling the history of scientists to the students. According to responses to item 15, all teachers respond that nonverbal intervention (facial expression, eye contact, touching the student, walking toward the student) should be used. The purpose of this verbal intervention is not to destruct (disturb) the teaching and learning process.

According to responses to item 17, most teachers argue that setting classroom rules creates well-behaving (no disturbance, no destruction, and students sit properly) students (01, 02, 04, 05, 07). Teacher 09 argues that the importance of setting classroom rules is to govern the teaching and learning process. Other teachers’ responses were irrelevant to the question. Moreover, the teachers argue that if students participate in setting the rule (01, 02, 03, 09), the rules are posted on the classroom wall (04), and the teacher implements the rules (05), the students respect the rules and feel ownership.

Teachers’ responses to item 18 were numerous and different. They respond a teacher maintain positive teacher-student relation: by calling students by their name (01); by understanding students (02, 09); by identifying and solving students problems (04); through discussion (04, 06), by looking all students equally (05); by advising misbehaving students (05); by accepting students comment (06); loving students (07); teaching students properly (08); using classroom rules properly (08); by setting communication rules (09) and by asking students’ needs (09). Only two teachers respond to the importance of positive teacher-student relations. They respond; it helps to develop students’ knowledge and achieve teaching and learning goals.

According to responses to item 19, all teachers argue that for minor misbehavior, a teacher should start with non-verbal intervention to avoid destruction in the classroom and because a misbehaving student may regret it easily with non-verbal intervention. Response to items 12, 15, 17, 18 and 19 indicates that every teacher has good understanding of classroom management.

According to responses to item 13, except for two teachers (07, 08), all teachers disagree with teacher Kebede’s (see item 13) idea. They argue, allowing for an additional answer helps:

- Students express their idea and participate in class (01, 04).
- Students learn from their mistakes or misconceptions (04, 06, 09).
- A teacher assesses students' understanding (03).
- A teacher identifies students' difficulties (09).

The two teachers (07 and 08) agreed with teacher Kebede because no extra time was wasted, and the teacher should use her/his time correctly.

According to responses to item 14, except teacher 06, all teachers appreciated teacher Kebede's effort. However, they argue that teacher Kebede's method was teacher center (01, 02, 03); it restricts students reading and sharing ideas (05); he has to use other methods. A teacher is a facilitator, not a feeder of all things (all information) (09). Teacher 06 argues that teacher Kebede is a model.

According to responses to item 16, teachers respond that the seating arrangements are: U-shaped or circular (02, 04, 06, 09) and its purpose is the students can easily share ideas; grouping students according to their level (01, 03) because students learn from each other; triangular and the purpose is to control the students (03).

According to responses to item 20, all teachers argue that a teacher should use different teaching methods because it helps students not to be bored by a single method (01); each content has its approach (01); it helps to address students with different learning styles (02, 05) and background (08) in a class; and it helps a teacher to conceptualize the idea (04). Responses to items item 13, item 14, item 16, and item 20 indicate that the teacher 02, 04, 05, and 09 have a good understanding of teaching methods, constructivist belief, and a good understanding of seating arrangement for specific teaching methods. Teachers 01, 03, 06, 07, and 08 have an average understanding of the teaching methods.

According to responses to item 11, all teachers except for teacher 08 agreed that a teacher should know his/her students because a teacher should know his/her students about their capacity, background, educational status, and his/her understanding, and level of communication. Teacher 05 argues that there is no need for knowing students in large class sizes, which indicates that the teacher agrees with knowing students, but it is difficult to know each student in a large class.

Teachers raised different complementary ideas about what teachers should know about their students. They argue a teacher should know about students' knowledge level, capacity, and status (01, 02, 03, 04, 05, 07, 09), students' behavior (02, 03, 05), and students' background (09). The teachers argue that knowing students help a teacher get full information about students, sort students according to their knowledge levels, follow up the students (02), and teach them (01, 02, 09). Only two teachers respond to how a teacher knows about his/her students. They respond through the teaching-learning process (05) and by asking students about their life.

According to responses to item 21, Five teachers' responses were not relevant to the question (01, 02, 03, 07, and 08). The others respond the knowledge domains are cognitive (04, 06 and 09), affective (04 and 06), and psychomotor (05), which indicates that most of the teachers from both groups were not aware of the three learning domains.

Teachers' responses to item 22 were fragmented. They respond, the purposes of assessment are: a way of checking or knowing students development or understanding (01, 03, 04); evaluating teaching method and students by giving test final homework (01, 02); following up of students and teaching and learning process (05, 07); a way of identifying students understanding (06); and it is a way of gathering information about students knowledge, skill, and attitude. Three teachers respond that a teacher can assess at the beginning, during, and at the end of the class (03, 05, 09). No one explained the purpose of each phase of assessment.

From responses to item item 11, item 21 and item 22 four teachers (01, 02, 06, 07 and 08) have average understanding and five teachers (03, 04, 05 and 09) have good understanding on classroom assessment.

In general, teachers believe that a teacher should know his/her students. As they mentioned in their response to items 11 and 22, a teacher should know students' understanding, capacity, and status, and a teacher should know his students to choose appropriate methods. Moreover, a teacher should know his students to plan and decide for a better teaching-learning process. These can be done through the teacher's classroom assessment. A teacher can implement the three phases of classroom assessment. From the response to the item 21, only three teachers have a better understanding of the three phases of classroom assessment, and all teachers have no understanding of the importance of the three phases. Teachers have no concrete understanding of the three learning domains, which creates a problem in preparing or choosing tests that ask three learning domains and contain different cognitive levels.

From teachers' responses to item 12, 15, 17, 18, and 19 they have a good understanding on the importance of motivating students, how to intervene minor miss behavior without distracting the class, and the importance of classroom rules. They have listed techniques for motivating students. The teachers have different understandings of how to make students respect classroom rules. Responses to items 14, 15 and 21 show that most teachers believe: students learn from their mistake; teacher-centered class discourages students' exploration (reading, searching for information) and pear teaching; and different teaching methods did not make students bored, address different topics and learning styles and makes students conceptualize about the topic.

Table 4.13,and Figure 4.22 summarized teachers' response to item 11-22 (Appendix C). Every teacher has a good understanding of classroom management; most teachers have an average understanding of the method of teaching; Most teachers have a good understanding of classroom assessment. When we compare teachers who have and have no training on DT:

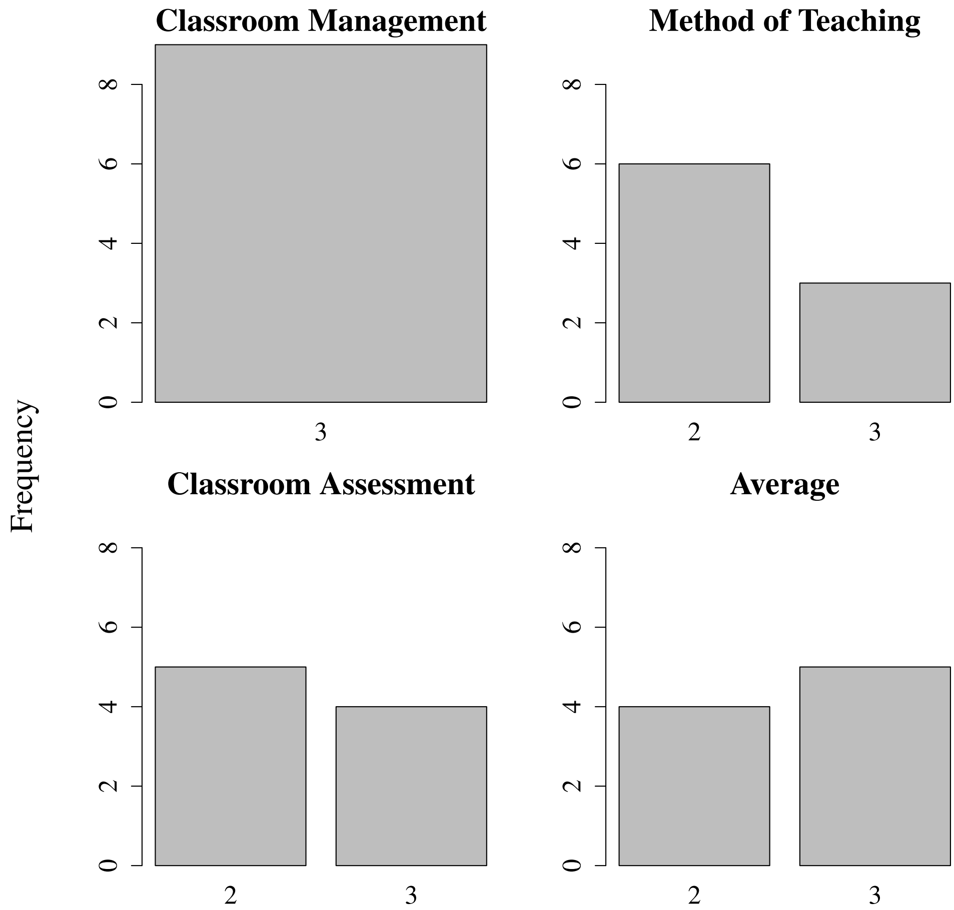
- 50 % of trained teachers have a good understanding of teaching method, and 50 % have average understanding while untrained teachers have 20 % good understanding and 80 % have average understanding; 50 % of trained teachers have a good understanding of teaching method; and
- 50 % of trained teachers have a good understanding of classroom assessment, and 50 % have average understanding, while 40 % untrained teachers have good understanding and 60 % have average understanding.

These indicate that training on DT has an impact on teachers' pedagogical knowledge.

Table 4.13: Pedagogical Knowledge as manifested in questionnaire

Teacher	Trained	Service Year	Pedagogical Knowledge			
			Classroom Management	Teaching Method	Classroom Assessment	Average
01	Yes	6	3.0	2.0	2.0	2.3
02	Yes	3	3.0	3.0	2.0	2.7
03	Yes	4	3.0	2.0	3.0	2.7
04	No	8	3.0	3.0	3.0	3.0
05	No	6	3.0	2.0	3.0	2.7
06	No	11	3.0	2.0	2.0	2.3
07	No	3	3.0	2.0	2.0	2.3
08	No	10	3.0	2.0	2.0	2.3
09	Yes	12	3.0	3.0	3.0	3.0
		Average	1.9	1.8	1.9	1.9

Note: 0 = very poor, 1 = poor, 2 = average, 3 = good, 4 = very good



PK: 0=very poor, 1=Poor, 2=average, 3=good, 4= very good

Figure 4.22: Pedagogical knowledge manifested in questionnaire

Moreover, Figure 4.21 and Figure 4.22 show that the teachers have better manifested in the questionnaire than what they demonstrated in their class. These indicate that teachers have difficulty putting their PK into practice and implies teacher training institutes give attention to teaching practice and imply that teacher education policy should emphasize the teaching practice of pre-service teachers.

4.4.4 Teachers' PK as Revealed in Interview

Five questions were used in interviewing the teachers (Appendix D). The questions were developed to clarify what was ambiguous in classroom observations and triangulate the data in-classroom observation. There was no teaching aid used in most teachers' classrooms except for textbooks, chalk, and blackboard. According to grade 7 and 8 curricula, the medium of instruction is English, but almost all teachers use Amharic and English languages as medium of instruction. Most of the time, teachers raise law-level questions in the classrooms. These questions do not probe the understanding of students easily. Some teachers have been passing students' questions without responding or who accept students' wrong answers. Some teachers allow students to ask questions only at the end of their presentation. To reveal why these happen, teachers respond to the five questions. Every interview questions were not for every teacher; instead, the questions were for teachers who have problems and ambiguities observed in their classes. Table 4.14 shows interview items directed to the teachers.

Table 4.14: Interview questions and respondents

Question	1	2	3	4	5
Teacher	01, 02, 04, 05, 07, 08, 09	04, 05, 07, 08, 09	01, 03, 04, 05, 07, 08, 09	03, 04, 05, 06, 07, 08, 09	01, 02, ,03 04, 05, 06, 07
Total	7	5	7	7	7

Teaching aid makes the teaching lively as these affect our organs of speech and sight. According to Weber (1922), our perception about various things is based: 40 % on visual, 25 % on audio, 17 % on touch, 3 % on taste and smell and 15 % on other physical experiences. Teaching aids: supplement in verbal instructions, makes learning permanent, provide variety, help attract the attention of the students, saves time and energy, encourages the healthy classroom interaction, helps the teacher to create situations for teaching the beginners, help create a positive environment for discipline, helpful in meeting individual differences, helps in providing speech training to the pupils, enable the children to retain language items for a longer time, gives vividness to the learning situation, makes the abstract ideas concrete, provide good substitutes for the real objects and help in the development of various skills such (Nikky, 2010).

To reveal teachers' understanding of teaching aid, the questions were raised to seven teachers. The teachers' respond teaching aids: help students easily understand their learning and make teaching easy (01 04, 05, 07); help students develop their knowledge (08); facilitate teaching, learning process and help teachers organize their lesson (09); and makes students see what they have not seen in theory (02). These indicate that the teachers have an understanding of the importance of teaching aid, but, as observed in their classes, they were maybe reluctant to prepare or use the existing teaching aids.

Question item 2 directed to five teachers (04, 05, 07, 08, and 09) because most teachers use both Amharic and English languages as mediums of instruction in their class. Even some teachers use Amharic more frequently than English. Even though his English was not clear, not structured, and challenging to understand, the only teacher who was using English more frequently was teacher 07. Even when he wrote on the blackboard, it was not understandable, which is paradoxical. The teacher uses the English language to obey the grade 8 curriculum, which is intended to use the language as a medium of instruction.

All teachers recommend English and Amharic languages as languages of instruction in grades 7 and 8 because students' mother tongue is Amharic, and they have difficulty understanding what they learn in English. Students not to learn only in their mother tongue language Amharic, the curricula are prepared in English. Therefore, it is better to teach both in Amharic and English. Teacher 07 argues that he uses the English language because the curricula are prepared in English, and the medium of instruction is English, which indicates that teachers use the English language without having communication skills in the English language because curricula and other teachers use the Amharic language. After all, students could not understand the concept, and the teachers could not articulate their idea easily in the English language.

Seven teachers (01, 03, 04, 05, 07, 08 and 09) respond to item 3. They respond, we can know our students' understanding by asking questions; when students relate what they learn with their daily life; by their facial expression. For example, students nod when they understand; If they do their homework and/or classwork and participate in activities. These indicate that the teachers have an understanding of how to know their student's understanding. However, they do not thoroughly probe their students by raising other questions based on students' answers.

According to Briggs (2017), there are 21 ways to check for students' conceptual understanding (Briggs, 2017). From teachers' responses, the teachers mainly use questions to assess their students' understanding, and a few students use students' facial expressions and classwork and homework. As observed in the classes, the questions were low-level (Briggs, 2017).

According to responses to item 4, all teachers (03, 04, 05, 06, 07, and 08) except teacher 09 argue that a teacher should not accept that he/she does not know. Instead, the teacher asks other students to answer the question, give the question to the student as homework or an assignment. The next day, the teacher should prepare for the question and make the students reflect on what they have got and finally answer the question. These teachers argue that accepting their mistakes leads students not to trust them in the future. Therefore, they choose to cheat and have an authoritative view. Teacher 09 argues differently: I admit that I do not know, and I give students a chance to answer the question. If no one can answer the question, I take the question as an assignment, and for the next period, I will be prepared and answer the question with students. If a teacher does not know the answer, he/she should admit it and ask the students to search for the answer and present it in the next class. No one can answer all questions raised by students.

Interview item 5 raised because most teachers have been giving their students a chance to ask what is not clear to them at the end of their presentation. Seven (01, 02, 03, 04, 05, 06, and 07) teachers respond to this question. Four teachers (02, 03, 06, 07) respond–it is better if a teacher admits students question during his/her presentation. Otherwise, a student who raised a question: may forget the question; remains there without understanding; and challenged to follow the teacher. The other three teachers (01, 04, and 05) respond–it is better if the teacher admits students' questions at the end of the teacher's presentation. Because there is limited time to cover the lesson of the day, and students who follow the teacher attentively are interrupted.

These indicate that teachers allow students to ask questions at the end of their presentation in their classes for two reasons. The first reason is the time constraint to accomplish the lesson of the day. The second reason is that the teachers have no understanding that the preceding concept impacts the understanding of the next concept, especially in science.

In general, teachers' responses revealed that there were teachers who believe that teachers know everything that they teach and have an authoritative view. Most teachers have difficulties in communicating in the English language. These beliefs and difficulties lead to misunderstanding and poor classroom management. Most teachers respond that we know our students' understanding by asking questions. However, they did not make it clear what kind of questions they used. As observed in the classes, they raise low-level questions.

Even though the teachers listed the importance of teaching aid in the classroom, most of them did not use it, which indicates that the teachers were reluctant to prepare or use teaching aids in their classroom. They also have limited knowledge of the importance of teaching aid. Some teachers also believe that it is better if students ask questions at the end of their presentation.

4.4.5 Summary

As observed in Table 4.12 and Table 4.13, teachers PK manifested in response to teachers' questionnaire was better than observed in their class. Notably, almost every teacher has manifested their PK very well in their response to the teachers' questionnaire than they demonstrated in their class. These indicate that the teachers could not apply their pedagogical knowledge in their class. Therefore, they lack skill in integrating their content knowledge and pedagogical knowledge.

As follows, teachers' pedagogical knowledge is compared with respect to teachers' who attend DT training. As the analysis indicates, teachers' pedagogical knowledge was almost similar between trained and untrained teachers.

4.4.5.1 Classroom Management

Physical Design of the classroom

- Evry teacher's classroom in both groups (trained and untrained) was the same.
- In both groups, there were variations in class size. It varies from 27 to 60 per class.
- Students seating arrangements in the trained group classes were more of a U-shaped, while in the non-trained group, three or two students were sitting at the same desk facing toward the blackboard.
- In both groups' class, there was no classroom decor.
- Except for one classroom, there were clear pathways for movement for both students and teachers in every classroom.
- In every class, there was no teachers' table and chair.

Rules and routines

- In both groups' classes, there were no classroom rules and rustiness developed and posted.
- As a result, students answered questions in the chorus, and there was no attendance.

Developing relationships

- Except in one teacher's class from the trained group, all teachers were caring.
- Because of difficulties in communicating in the English language, all teachers in both groups except one teacher in untrained group use Amharic as a medium of instruction and motivate and initiate their students in Amharic.
- Because of the lack of planning in some teachers' classes in both groups, some students were not engaged in problem-solving and discussions on questions posed by the teacher.
- Extremely redundancy of ideas in most classes in both groups were observed.

Discipline

- In both groups in some teachers' classes, minor misbehaviors were observed. Such as talking out of topic, looking outside, and horseplay.
- For these minor misbehaviors, every teacher used verbal and non-verbal intervention.

- From both groups, most teachers have listed how to intervene with students' minor misbehavior.
- All teachers in both groups have different beliefs on how to make student respect classroom rules.

4.4.5.2 Teaching Methods

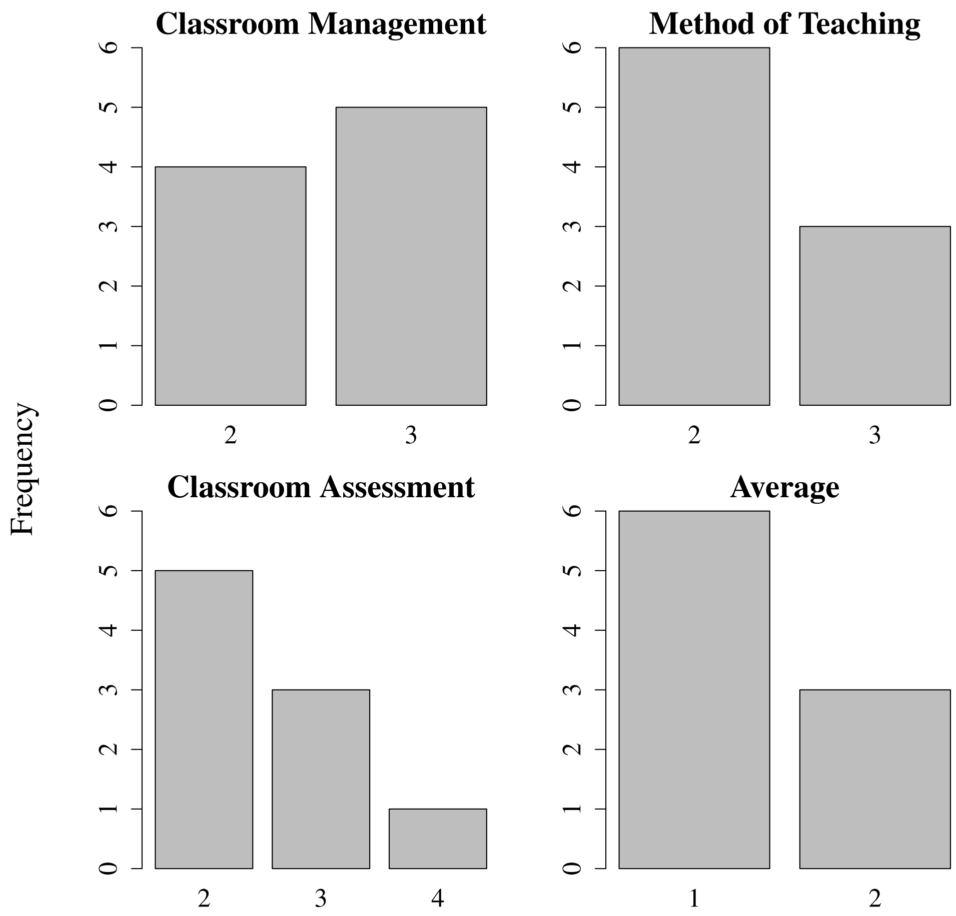
- In both groups, question and answering and demonstration methods have been used.
- In both group lecture method was used by most teachers intensively–especially those groups who have no training.
- Both groups have no excellent command of the English language, and they recommend students should learn in their mother tongue.
- In both groups, most teachers tried to use the discussion method, but the discussion lacks planning.
- Questions raised in question and answering in both groups class were not scrutinizing and challenge students' understanding.
- In the problem-solving method, there were teachers in the untrained group whose questions were not clear and lacked appropriate data.
- Most teachers from both groups believe that students learn from their mistakes and their peers. They also argue that different teaching methods help students not be bored and address different learning styles.
- Both groups argue that teaching aid facilitates the teaching and learning process, but most teachers did not use teaching aid in their classroom.
- Most teachers from both groups have an authoritative view. They argue a teacher should not accept if he does not know about what he teaches. Only one teacher from a trained group argues that a teacher should be able to say, "I do not know" what he does not know and initiate students to search for that.

4.4.5.3 Classroom Assessment

- Teachers in both groups used three primary methods to gather information for assessment.

- In both groups, there were teachers who were not a critical observer of their students' activities.
- All teachers in both groups intend to use oral questions as a primary method to gather data.
- Also, some teachers from both groups argue that a teacher can assess his/her students' facial expressions.
- In both groups, there was a limitation in giving feedback to students' responses.
- All teachers from both groups agree that a teacher should know his/her student.
- From both groups, most teachers did not differentiate the learning domains they intended to assess.
- From both groups, teachers could not mention the three phases of classroom assessment and their purpose. However, three teachers from both groups have listed the three phases.

In general, from both instruments: classroom observation and questionnaire, as shown in Figure 4.23, four teachers were average, and five teachers were good in their classroom management; six teachers were average, and three teachers were good in their method of teaching; five teachers were average, three teachers were good, and one teacher were very good in their classroom assessment.



PK: 0=very poor, 1=Poor, 2=average, 3=good, 4= very good

Figure 4.23: Pedagogical knowledge

4.5 Analysis of Teachers' Pedagogical Content Knowledge

4.5.1 Introduction

This section attempted to address a research question 3, which intended to uncover grades 7 and 8 physics teachers' TSPCK on Newtons' laws of motion and graphical representation of motion. For the deeper investigation, I focused on case study groups. There were two groups: groups who trained and those untrained in DT. The trained group comprises four teachers (01, 02, 03, 09) and an untrained group of five teachers (04, 05, 06, 07, 08). Each teacher has introduced and their TSPCK with respect to Newtons' laws of motion and graphical representation of motion using their CoRes, lesson plans, classroom observations, and questionnaires were explored.

4.5.2 Teachers' PCK as portrayed in CoRes

4.5.2.1 Teachers' CoRes

Templates of CoRe for grade 7 and grade 8 are shown in Appendixes (A.1 and A.2) respectively. Each template has eight prompt questions. Nine teachers responded to the prompts, and their responses were analyzed.

According to responses to the prompt question 1 in the Appendixes (A.1 and A.2), grade 7 teachers did not list every content that students should learn in those big ideas, and what they mentioned were not clear. Teacher 01 intended that the students to learn motion in relation to our daily life, external force moves an object, acceleration is directly proportional to force and inversely proportional to mass, two bodies exert the same force on each other. Teacher 05 intended students to learn inertia, unit of inertia, inertia, and mass, relate inertia with their life, force and acceleration, action, and reaction forces. Teacher 06 intended students to learn inertia, objects at rest continuous at rest unless unbalanced force exerted, and Newton's second law. Teacher 08 did not list what students learn, rather she said "I teach as per the textbook." Teacher 05 has mentioned better what she intended the students to learn. Therefore, grade 7 teachers have limited knowledge of the contents they were going to teach about the three main ideas. Specifically, teacher 08 did not mention the contents the students are going to learn in the big ideas.

Except teacher 07, all grade 8 teachers have listed what they intended the students to learn about the two big ideas. The contents are $s-t$ graph, $v-t$ graph, $a-t$ graph, the slope of the $v-t$ graph, and distance-time graph and the area under the curve of the $v-t$ graph. Teacher 07 clearly did not mention the contents the students are going to learn under the two big ideas. What teacher 07 mentioned was not clear ("Be attend to students about uniform motion, the object move to constant speed of on the same speed when constant force applied on the object then ideally.")

When we compare trained teachers with untrained teachers in DT, except teacher 01 who was teaching in grade 7, all teachers have listed the contents they intended to teach under the topics. But from untrained teachers, four teachers did not list contents under the topic they intended to teach. Three teachers were from grade 7 and one teacher from grade 8. Only one teacher from the untrained group listed what he intended to teach under the topic.

According to responses to the prompting question 2 in Appendixes (A.1 and A.2), all grade 7 teachers did not mention clearly the importance of the three big ideas. Teacher 05 argues that the three big ideas are important for students in applying in their daily life, but did not mention how. Others considered defining the three laws as important to the students, which does not mention how important it is. Except teacher 07, all grade 8 teachers argue that the importance of learning the two ideas are students identify concepts related to $s-t$, $v-t$ and $a-t$ graphs (02); solve problems in motion (03, 04); and interpret graphs and use for future learning (09). What teacher 07 mentioned was not clear and different from the big ideas.

When we compare the trained group with the untrained group, from grade 8, from the untrained group, teacher 07 could not mention the importance of the topic for the students, whereas teachers in the trained group teaching grade 8 physics were well explained–the importance of the topic. Similarly, grade 8 physics teachers mentioned the contents they are going to teach than grade 7 teachers.

According to responses to item 3 in Appendixes (A.1 and A.2), from grade 7, two teachers (01, 05) did not respond to this prompt and responses of other teachers (06, 08) were not relevant to the prompt: What else they know about the big ideas. For example, teacher 08 responded, " I will teach them". Therefore, the teachers have no more idea about the three big ideas. Grade 8 teachers respond, what they know about the two big ideas but didn't intend students to know yet are the graphical representation of free fall (02); graphical representation of projectile motion, $s-t$ graph for uniformly accelerated motion and motion in two or three dimensions (04); and calculations in $v-t$ graph and $s-t$ graph in uniformly accelerated motion (09). The teachers argue that these concepts are beyond their level. The response of teacher 07 was not clear and irrelevant to the prompt.

When we compare both trained and untrained groups, teachers from both groups teaching in grade 7 could not respond well. All grade 8 teachers from both groups responded except teacher 07 from the untrained group. Therefore, the trained group has better responded than the untrained ones. Regarding grade 7 and grade 8 teachers, grade 8 teachers have better performed than grade 7 teachers.

According to responses to item 4 in Appendixes (A.1 and A.2), grade 7 teachers respond, difficulties/ limitations connected with teaching these ideas are students could not memorize formulas and relate with their daily life (01); lack of laboratory rooms and materials and our countries development (05); no teaching aids (figures, diagrams and real objects) (06); and lack of students interest to the idea, lack of materials like colored chalk, students economic background, lack of time and miss much of the idea with the environment (08).

Grade 8 teachers respond that difficulties/ limitations connected with this idea are lack of students interest, lack of materials like colored chalk and Lack of time (02); students background knowledge about motion, the skill of students, the time allotted and students attention, a real example, introducing the rationale of the topic (03); describe uniform motion and uniformly accelerated motion in a straight line (04); uniform motion is ideal, object not move on the space, uniformly accelerated motion (07); and lack of materials like graph paper, prerequisite knowledge, students background and prerequisite knowledge (09). Both groups have well-mentioned difficulties in lack of resources and lack of students' interest in physics.

According to responses to prompting question 5 in Appendixes (A.1 and A.2), grade 7 teachers respond that knowledge about students thinking which influence their teaching are: students don't understand force and acceleration have relation (01); students language problem, students thinking ability are very low or they are not interested in their learning, students' family problem (05); cause of the motion of an object on road', students argue acceleration is the cause of force (06); students dislike the physics, third law contradict with the knowledge they have (08).

Grade 8 teachers responded, students' background knowledge about the graph, students' misconception, students' language problem, introduce the difference between uniform motion and uniform accelerated motion graphically (03); students hate the subject physics because of negative information about physics (04); prerequisite knowledge about the graphical representation of uniform motion and students ideology (07); lack of basic knowledge of interpretation of graph; Lack of drawing skill, lack of connecting their knowledge with daily life (09). Teacher 02 didn't respond.

Both trained and untrained groups have mentioned students' thinking (prior knowledge) which influences their teaching. But the teachers did not mention how they influence their teaching. For example, how the ideology of a student influences a teacher's teaching.

According to responses to prompting question 6 in Appendixes (A.1 and A.2), grade 7 teachers respond, lack of material for practical work, accepting two different objects pushing each other with equal forces (01); students age, environments, and society (05); lack of materials such as diagrams, the concepts are not visible (force and acceleration), Concepts in Newtons' law of motion are not fact (06); lack of parents support and follow up, the school is not conducive for teaching and learning and the contextual condition (08) influence their teaching.

Grade 8 teachers responded: students' family background, the time allotted, classroom size, misbehaving students, students' understanding and reading experience, student parents' problems, students' weak communication in the English language, students lack support at their home and lack of adequate resources (02, 03, 09) influence their teaching. Other teachers responded, lack of information about uniform motion on the graphical representation, students have no information about physics, Uniform motion is ideal, not real, no source about the graphical representation of uniform motion, speed of an object can't be constant (04, 07) influence their teaching.

Both groups have well-mentioned contextual conditions that can influence their teaching. What two teachers from the untrained group raised were not relevant–"Uniform motion is real, and I don't think there is any information about physics".

According to responses to the prompt question 7 in the Appendixes (A.1 and A.2), grade 7 teachers responded that the teaching procedures they intend to use were question-and-answering, lecture and demonstration, and group discussion. Teacher 01 intended to ask, brainstorming questions and students explain what they know, and based on students' answers and relating to the daily life of the students, she intended to explain the idea to the students, and using teaching aids demonstrate the concepts (inertia, newtons third law). Teacher 05's intentions were to introduce concepts in Newton's laws of motion at the beginning of the class and then give questions for discussion to the students and follow up with the students and give additional information during their discussion. Then students reflect on their discussions, and, finally, the teacher summarized the discussion by correcting students' discussion and gave short notes. Teacher 08 intended to make a participatory class by question and answering and group discussion. She did not explain how she uses the strategies. Teacher 06's responses were irrelevant to the prompt. For example, she said teaching is difficult because students can't see the concept easily.

Grade 8 teachers respond to teaching procedures they intended to use, demonstration, lecture, and question-and-answering. Teacher 02 intended to prepare materials such as graph paper, a meter stick, and a stopwatch, and then plot $s-t$ graph and $v-t$ graph. Teacher 03 was intended to introduce students' prior knowledge which is related to the uniform motion with the graph by demonstration and facilitates students to do problems in a group and individually and support students to explain the graph. For the second idea, she intended to introduce uniformly accelerated motion by starting from uniform motion and then demonstrate the students how to plot the graphs and ask how to plot the $a-t$ graph and $v-t$ graph and then tell the students about constant acceleration. Teacher 04 was intended to explain uniform motion and uniformly accelerated motion and demonstrate the graphical representation of motion ($v-t$ graph for both uniform and uniformly accelerated motions, and calculate the slope of the $v-t$ graph). Teacher 09 was intended to explain uniform motion and uniformly accelerated motion by the question-and-answering method and explain the graph of uniform motion and uniformly accelerated motion and then give group activity to assess how the students apply the slop formula and check their work and correct their work at the end.

Both groups have mentioned different teaching strategies they are intended to use. But there are teachers from the untrained group who did not make clear in implementing the strategies, for example, teachers 07 and 08. All teachers from both groups did not mention why they chose the strategies.

According to responses to item 8 in Appendixes (A.1 and A.2, both grade 7 and 8 teachers respond, they ascertain students' understanding or confusion around these ideas by asking questions and giving homework (01); by asking oral questions, giving classwork and giving abrupt (sudden) examination (05, 08). Teacher 06 and 07 responses were not clear and irrelevant to the prompt.

Most teachers intended to use questions and classwork, but from the untrained group, there were two teachers (06 and 07) who did not mention clearly how to ascertain their students' understanding.

4.5.2.2 PCK as demonstrated in Teachers' CoRes

Based on teachers' CoRes each component of their PCK was analyzed. The components are students' prior knowledge, curricular saliency, what is difficult to teach, Representation, and Teaching strategy (Mavhunga & Rollnick, 2013). As shown in Table 4.15 teachers' PCK was quantified using a guideline for quantifying PCK (Mavhunga & Rollnick, 2011). After quantifying, each component of teachers' PCK is presented and compared between trained and untrained teachers on DT.

Table 4.15 quantifies teachers PCK using the guidelines (Appendix A.3). The table shows, every component of teachers' PCK vary from 1 (limited) to 4 (exemplary) except knowledge of representation which varies from limited (1) to developing (3). When the average of components of teachers' PCK compered between teachers who have the training and have no training on DT: knowledge of students' prior knowledge of the trained teacher is 2.8 ($\approx$ developing) and untrained teacher is 2 (limited); knowledge of curricular saliency of the trained teacher is 2.5 ($\approx$ developing) and untrained teacher is 1.4 ($\approx$ limited); knowledge of what is difficult to teach of the trained teacher is 3

Table 4.15: *Quantifying teachers PCK as portrayed in teachers CoRes*

Grade	Trained	Teachers	Students' prior knowledge	Curricular saliency	What is difficult to teach?	Repres-entations	Teaching strategy	Average
7	Yes	01	3.0	2.0	2.0	3.0	3.0	2.6
	No	05	4.0	2.0	3.0	3.0	4.0	3.2
	No	06	2.0	1.0	2.0	1.0	1.0	1.4
	No	08	1.0	1.0	3.0	3.0	2.0	2.0
8	Yes	02	3.0	1.0	3.0	2.0	1.0	2.0
	Yes	03	2.0	3.0	3.0	2.0	3.0	2.6
	No	04	2.0	2.0	2.0	3.0	3.0	2.4
	No	07	1.0	1.0	1.0	1.0	1.0	1.0
	Yes	09	3.0	4.0	4.0	2.0	4.0	3.4
Average		All	2.3	1.9	2.6	2.2	2.4	2.3
		Trained	2.8	2.5	3.0	2.3	2.8	2.7
		Untrained	2.0	1.4	2.2	2.2	2.2	2.0

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

(developing) and untrained teacher is 1.4 (≈ limited); knowledge of representation of trained teacher is 2.3 (≈ basic) and untrained teacher is 2.2 (≈ basic); knowledge of teaching strategy of the trained teacher is 2.8 (≈ developing) and untrained teacher is 2.2 (≈ basic).

These all indicate that in each component of teachers' PCK, teachers who have training inDT have better demonstrated their PCK on teaching SCPS physics than untrained teachers. Therefore, training on DT has a positive impact on teachers PCK. Next, teachers' components of PCK are explained, how they elaborated in their CoRe.

Students' Prior Knowledge

The teachers have identified different students' prior knowledge. They identified students' poor English knowledge; lack of skill of plotting graphs, difficulties of differentiating uniform motion, and uniformly accelerated motion; think that force and acceleration have no relation. Even though it is not, there was a teacher who identified a lack of interest in learning physics as prior knowledge.

Students' prior knowledge identified by trained groups comprises both general students' knowledge and specific to the topics they were teaching. On the other hand, those who have no training in Dialogic teaching have identified students' prior knowledge, which is generic. Some teachers did not make clear what they identified as prior knowledge, for example, teacher 07 identified students' ideology as students' prior knowledge.

In general, the teachers did not identify common students' prior knowledge such as a body moves with constant velocity due to net applied force; interpreting a graph, and a body accelerates when action force is greater than the reaction force. In fact, these misconceptions were reflected with teachers themselves.

Curricular Salience

Grade 7 teachers could not provide all contents to be addressed. What they provided were not well explained–for the three big ideas (inertia, acceleration is proportional to the applied net force, and for every action force there is equal and opposite reaction force). What teacher 08 provided as content for the three big ideas were irrelevant. Since what the teachers were provided was limited, it was difficult to decide whether or not the concepts were provided in a logical sequence. Every teacher did not provide prior-concepts that would help them to introduce the lesson of the day.

Except for one teacher from grade 8, all teachers provided content to be addressed in the big ideas (Graphical representation of motion in uniform motion and uniformly accelerated motion). Except for teacher 07, all grade 8 teachers have provided a logical sequence of concepts. The teachers identified that the importance of concepts in the two big ideas is identifying concepts in graphs, solving problems concerning motion, and interpreting graphs. What they provided as the importance of the concepts in big ideas were not provided by each teacher. What teacher 07 provided as the importance of the concepts in big ideas were not clear and irrelevant.

In both groups (trained and untrained) there were teachers who mentioned contents to be addressed very well, and there were also teachers who didn't mention contents to be addressed. There were teachers who didn't make their ideas clear. For example, teacher 07 said, "Be attend to students about uniform motion, the object move with a constant speed of on the same speed when a constant force applied on the object then ideally".

What makes the topic difficult to teach

Both grade 7 and grade 8 teachers state that limited resource (teaching materials, the time allotted and information about the topic) (05, 06, 08, 02, 07, 09), difficult and complex concepts (uniform and uniformly accelerated motion are not real and complex concepts, introducing rationale of the topic) (03, 04), contextual problems (class size, students background, the problem of the countries, non-conducive environment) (08, 02,03) and students problem (language, behavior, skill, memorization, interest to learn, prerequisite knowledge, parent) (02, 03, 09) make the topic difficult to teach the topic. All teachers did not explicate how they make the topic difficult. For example, how country development, environment, and parents' support make the topics difficult to teach.

Teacher 07 stated that information about uniform and uniformly accelerated motion is limited. I do not think there is any information about these concepts. Again, teacher 07 stated that no object moves with constant velocity or uniformly accelerated motion makes the topic difficult to teach. He argues that the two concepts of uniform motion and uniformly accelerated motion are ideal. This argument is far from the fact that there are objects that move with uniform motion or uniformly accelerated motion. Teacher 07 himself has misconceptions about uniform and uniformly accelerated motion.

When we compare the two groups (trained and untrained), both groups have provided well, what makes the topics difficult to teach. However, teacher 07 from the untrained group has no clear understanding of "what makes the topic difficult to teach."

Representations including analogies

In teachers' CoRes, some teachers tend to use explanatory note (01, 06, 02), demonstration (02, 03), verbal explanation (05, 08, 01). These indicate that either the teachers are unaware of multiple representations or have no interest in using multiple representations. Multiple representations address students' learning styles and enhance the students' understanding –however, No one intended to use an analogy, diagrams, charts, posters, and others.

Conceptual Teaching Strategies

Teaching strategies identified by grade 7 and 8 teachers were question and answering, lecture and demonstration, and group discussion. Five teachers (01, 05, 03, 04, 09) have justified the teaching procedures they have chosen for the big ideas.

Most teachers (01, 05, 08, 03, 09) intended to make the class both teacher-centered and student-centered from teaching strategies chosen and their justifications. Moreover, two teachers (02 and 04) intended to make their class more teacher-centered. When we compare trained and untrained teachers, most teachers from trained groups intended to make their class both teacher-centered and student-centered. There were teachers from the untrained group who could not make their strategies explicit.

4.5.3 Teachers' PCK as manifested in Lesson Plan

4.5.3.1 Teachers' Lesson Plan

CoRes may be limited in providing insights about teachers PCK, hence Loughran et al. (2008) used Pedagogical and Professional Experience Repertoires (PaP-eRs). Analyzing teachers CoRe revealed not complete evidence of teachers PCK. Therefore, the potentials of other sources, such as lesson plans and classroom observation, were used to explore teachers' PCK further.

In the lesson plans, how the participants transformed their content knowledge of Newtons' law of Motion and graphical representation of Motion into teachable content was explored. Hence, teachers' reasoning, thinking, and actions in the teaching of Newtons' laws of Motion and graphical representation were explored.

For grade 7, teachers' lesson plans on Newton's law of Motion and grade 8 teachers' lesson plans on Motion's graphical representation were examined. The teachers used the modified USAID-AED/EQUIP II (2008) lesson design template (see Appendix B.1) to develop their lesson plans. The teachers have been using this lesson design template. Therefore they were familiar with the components in the rationale for the lesson design template. Teachers are accustomed to lesson plan activities so that they may articulate their intention better in lesson plans than in theCoRe template.

Teachers have chosen one of the big ideas from a CoRe and developed a lesson plan on it. The lesson plans they developed were used as a data source. The teachers had the freedom to choose one big idea. Teachers' classrooms were observed during their class on the designed lesson plan. During the lesson plan preparation, the teachers know they will be observed on the day of the lesson.

Rationales of the topics

The rational of a lesson is a justification for doing the lesson. Each teacher provided the rationale for their lesson. Rationales they have provided were to prepare students for a higher grade (01, 02, 03, 09), students apply concepts and laws and use them in their daily life (01, 05, 04, 04, 07, 08, 09), and students differentiate concepts (06). The rationales most teachers provided were not justified very well. For example, they said that students use in their life. However, they did not mention how they use it.

Pre-requisite Knowledge

All teachers provided pre-request knowledge. However, what they have provided was not specified, irrelevant, or not explicit. From the provided pre-request knowledge, teacher 03's was more appropriate. These indicate that the teachers are not aware of where to start the lesson. Students construct their knowledge based on what they know. Their knowledge is dependent on what they have learned before, formally in the classroom or from their environment.

Learning Objectives

The objective of a lesson is what students accomplish in the lesson. Objectives of the teachers' lessons mainly focused on one of the learning domains: the cognitive domain. Most teachers focus on lower-level cognitive domains. They have identified some keywords– describe, state, define, manipulate/calculate, plot, interpret, and explain.

Introduction

In the introduction part of the lesson plan, the teachers did not specify the contents they intended to review. What most teachers mentioned were generic. In the teacher's activity column, four teachers (01, 05, 06, 03) intended to ask questions, give explanations, and/or demonstrate the previous lesson or lesson of the day, which was not mentioned clearly. Teacher 08 has mentioned what she intended to ask the students. Teachers intended the students to answer questions, listen, participate, remember, recall, and ask questions under students' activity. The teachers intended to assess students' prior knowledge by asking questions. Except for two teachers (08, 03), teachers did not mention the questions they intend to ask. Two teachers (04, 07) intended to assess their students' prior knowledge by asking what they learned last time.

Lesson Development (presentation)

In lesson development, teachers mentioned what they intended to do during instruction under the teacher's activity column. They asked questions, gave short notes, explained lessons of the day, demonstrated lessons of the day, and facilitated group discussion. Four teachers (01, 05, 06, and 08) have chosen more teacher-centered methods, and others (02, 03, 04, 07, and 09) have chosen more student-centered teaching methods. Teachers (04, 07, and 09) have mentioned teaching procedures they intended to follow in the class, whereas other teachers did not show clear procedures they intended to follow.

The teachers intended students' activities were answering questions, taking notes, attentive listening, forming groups, and discussing in a group. They mentioned instruments they intended to use, including oral question and observation techniques, to assess students' understanding. Teachers (01, 02, 03, 04, and 09) have provided some oral questions they intended to ask during the instructions, while others did not mention the questions they intended to ask.

Conclusion (stabilization)

In the lesson plan's conclusion, the teachers intended to ask questions, give a summary of the lesson, do examples, revise the main points, write main points in the blackboard, give chances to the students to ask, and/or give homework. There were teachers (03, 04, 08, and 09) who mentioned their activities very well. Other teachers did not specify their activities. Teachers intended the students to do activities such as responding to questions, listening to their teacher and peers, taking correction, and/or work in a group.

Assessment

After instruction, in assessing students, teachers intended to ask oral questions, give classwork, support students who could not answer questions, and give group activities. There were teachers (02, 05, 06, 07, and 09) who mentioned what they intended to do correctly. Teachers intended students to answer, listen, do homework, take correction, and/or work in a group.

Teaching and Learning Materials

Grade 7 teachers intended to use teaching materials (resources) like teacher guides, textbooks, different masses, and students. Grade 8 teachers intended to use textbooks, chalk, duster, teacher guide, syllabus, square paper, and graphs. Teacher 05 did not mention materials; instead, she explained activities she intended to do in the class. For example, she said, ”Two persons push each other, upward-moving rocket, and raising a book on a palm.”

Learner Support

Mainly, the teachers mentioned how to support slow learners. They intended to support slow learners by giving simple questions, giving different activities, making fast learners help, giving additional examples, giving a worksheet, and grouping them with fast learners. For students who have a disability in hearing, teacher 03 intended to support by giving worksheets, writing on the blackboard, and speaking loudly during his presentation.

4.5.3.2 PCK as demonstrated in Teachers' Lesson Plan

In this subsection the five components of teachers' pedagogical content knowledge were analyzed based on the teachers' lesson plans.

Table 4.16: Quantifying teachers PCK, based on teachers lesson plan

Grade	Trained	Teachers	Students' prior knowledge	Curricular saliency	What is difficult to teach?	Repres-entations	Teaching strategy	Average
7	Yes	01	1.0	1.0	1.0	2.0	2.0	1.4
	No	05	1.0	1.5	1.0	2.0	2.0	1.5
	No	06	1.0	1.5	1.0	1.5	1.5	1.3
	No	08	1.0	1.0	1.0	1.0	2.0	1.2
8	Yes	02	1.0	1.5	1.0	2.0	2.0	1.5
	Yes	03	2.0	3.0	1.0	3.0	2.5	2.3
	No	04	1.5	1.5	1.0	1.5	1.5	1.4
	No	07	1.0	1.0	1.0	1.5	1.5	1.2
	Yes	09	1.0	2.0	1.0	2.5	4.0	2.1
Average		All	1.2	1.6	1.0	1.9	2.1	1.5
		Trained	1.2	1.9	1.0	2.4	2.6	1.8
		Untrained	1.1	1.3	1.0	1.5	1.7	1.3

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

Table 4.16 quantify teachers PCK using the guidelines (Appendix A.3). The table shows components of teachers' PCK vary: for students' prior knowledge from 1 to 2; for curricular salience from 1 to 3; for representation from 1 to 3 and teaching strategy from 1.5 to 2. There was no significant variation for what is difficult to teach, and it was 1 (limited). Even though the teachers were accustomed to the lesson plan, they did not demonstrate their PCK in their lesson plan. When the average of components of teachers' PCK compered between teachers who have the training and have no training on DT: knowledge of students' prior knowledge of the trained teacher is 1.2, and untrained teacher is 1.1; knowledge of curricular saliency of the trained teacher is 1.9, and untrained teacher is 1.3; knowledge of what is difficult to teach for both group was 1, which were the same; knowledge of representation of trained teacher is 2.4, and untrained teacher is 1.5, and knowledge of teaching strategy of the trained teacher is 2.6, and untrained teacher is 1.7.

These indicate that in each component of teachers' PCK, similar to the data obtained from teachers' CoRes, teachers who have training on DT have better demonstrated their PCK on teaching grade SCPS physics than untrained teachers. Therefore, training on DT has a positive impact on teachers PCK. Next, how they elaborated in their lesson plan, teachers' components of PCK were explained.

Students' Prior Knowledge

As the teachers mentioned in pre-requisite knowledge, introduction, and learner support parts of their lesson plans, both groups have not shown their students' actual knowledge. They are well aware of slow learners and fast learners. They have stated well how to support slow learners in their class.

Curricular Salience

Main contents grade 7 teachers should consider when teaching about Newton's laws of motion are: In Newton's first law, inertia, mass is the measure of inertia, an object tends to remain in its state of motion unless an external unbalanced force acts on it and examples of impacts of inertia in our daily life; in Newton's second law the acceleration of a body is related to the net force applied and mass of the body, weight, and mass, units of force and applications of Newton's second law; and in Newton's third law the existence of the action and reaction force in pair, the two forces are equal in magnitude and opposite in direction, and applications of Newton's third law in our daily life.

All teachers provided the contents to be addressed in their lesson plan. The contents provided were generic. They did not provide subordinate ideas to be discussed. There were no explanations or definitions given about the contents provided. The reasons provided for the lesson were not specific to the topic. For example, they stated that the contents are essential for the future in higher grades.

Contents that grade 8 teachers should consider in graphical representation of motion in grade 8 are $v-t$ an $s-t$ graphs, slope of s-t graph and area under $v-t$ graph in uniform motion and $v-t$ and $a-t$ graphs and slop of $v-t$ graph for uniformly accelerated motion. Whereas grade 8 teachers did not mention full contents in graphical representations of motion; rather, they mentioned a graphical representation of motion for uniform motion and uniformly accelerated motion. Already they mentioned these contents as a topic of the day. Both groups have not explained the contents of the topics students should learn.

What makes topic difficult to teach

From teachers' lesson plans, there was no clue from both groups that showed the topics were difficult for the students.

Representations including analogies

Parts of lesson development and teaching materials did not show representations. In lesson development, the teachers intended to use verbal representations, but they listed some visual materials for demonstrations. For example, teacher 06 provided masses and tables in teaching materials, whereas she did not mention how to use the material in her teaching procedure. Also, teacher 09 provided materials such as a graph chart, which uses for visual representation, but he did not mention how to use it in his teaching procedure.

Both groups (trained and untrained) intended to use verbal representations, and some teachers tend to use visual representations from both groups.

Conceptual Teaching Strategies

Each teacher has chosen two or more teaching strategies. They did not provide the procedure they follow in using the teaching strategies. Grade 7 teachers have chosen more teacher-centered strategies, and grade 8 teachers have chosen both teacher-centered and student-centered approaches. There was no justification given for the chosen teaching strategies.

4.5.4 Teachers' PCK as Observed in Physics Class

In this subsection, teachers' TSPCK explored based on video-based classroom observation. In a class, the teacher's real TSPCK is revealed.

Students' Prior Knowledge

Except for what the students learned in the previous lesson, grade 7 teachers did not emphasize their prior knowledge. The teachers try to assess students' understanding of the previous lesson by asking questions. They have been raising more of remembering (lower level) questions.

All grade 8 teachers except two teachers (03 and 09) did not consider students' knowledge of a graph, which is essential to teach the graphical representation of motion. Every teacher starts with previous lessons, motion (velocity, displacement, and acceleration), but teacher 04 did not, instead, start with Newton's laws. Students' knowledge of a graph may help the teachers know how much they understood the previous lessons and progressed to the next lesson or review the previous lesson. The teachers need to introduce the basic concepts in plotting graphs such as vertical and horizontal axes (x and y axes). In the graphical representation of motion, what do x and y axes represent? Teacher 04 raised about Newton's law of motion in his introduction as part of the graphical representation of motion, which is not relevant. For this topic, concepts that should be raised in the introduction were velocity, acceleration, displacement, time, and their mathematical relation to the day's lesson: graphical representation of uniform motion.

Teacher 04 has no prior knowledge of his students. He has been driving equations of motion for uniformly accelerated motion. It was better if he used the concept of the area under a $v-t$ graph for uniformly accelerated motion to compute the displacement of an object in a given time interval.

Teacher 09 has been asking students prior knowledge on how to compute the area of regular shaped regions before applying the concept "area under the $v-t$ curve is the displacement of an object in the given time interval." These make the next activity simple in finding the displacement using the area under the curve. Teachers from the trained group have a better understanding of students' prior knowledge than the untrained group.

Curricular salience

Grade 7 teachers have presented all contents of the topics. They provided content that helps students by asking questions in the introduction of their lesson. All teachers raised subordinate concepts in the topic. Their presentation revealed that the teachers had shown they had misconceptions about the contents of the topics. Teacher 08 considers the three laws of motion as effects of force; mass and inertia are the same; a body at rest has inertia, whereas that move has no inertia; Newton's first law is a body at rest. Most teachers could not deliver complete or clear definitions of Newton's first law of motion.

Grade 08 teachers raised subordinate ideas such as $s-t$, $v-t$ and $a-t$ graphs, slop of $v-t$ and $s-t$ graphs, and area under the curve of $v-t$ graph in their classes except for some teachers who did not raise all concepts in the topic. For example, teacher 02 did not present $v-t$ graph of uniform motion, area under the curve of $v-t$ graph and the slope of $v-t$ and $s-t$ graphs. At the end of her class, I asked whether she completed the topic's content or not, and she said yes, I completed the topic. These indicate that there are teachers who did not cover important concepts in a topic. When we compare both groups, both groups have raised contents in the topics with misconceptions.

What makes topic difficult to teach

In their classes, most teachers did not show any understanding of what makes the topic difficult to teach. Teachers 03 and 09 from the trained group have an understanding that teaching about the graphical representation of motion without introducing concepts in the graph (axes and slope) makes the topic difficult.

Some misconceptions make topics in Newton's laws of motion challenging to teach. For these misconceptions, grade 7 teachers did not give emphases to challenge students' misconceptions. For example, one common misconception is that to move an object with a constant velocity, we apply constant external unbalanced force, which contradicts Newton's law of motion. The misconception arises from the friction force, which is opposite and equal in magnitude with the externally applied force. However, most students have no understanding of the existence of friction force. Therefore, when we compare trained and untrained groups, the trained group identified what makes the topics difficult to teach.

Conceptual Teaching Strategies

Grade 7 teachers have been using question-and-answering, group discussion, demonstration, note giving, problem-solving, and lecture methods. Question and answering and lecture methods were used most frequently in every class. Every teacher has been using question-and-answering, note-giving, problem-solving, and lecture methods. Except for teacher 08, every teacher has been using the demonstration method. Group discussion was only used by two teachers (01, 08).

At the beginning of the class, every teacher was using a question-and-answering method. Question-and-answering was used to check students' understanding of the previous lesson and during lessons, development to check students' understanding. Questions the teachers have been raising were low level, and most teachers did not encourage students to develop their students' critical thinking. Teacher 01 asks probing questions based on students' answers, revealing whether students understand the concept or not and make students think critically.

The Group discussion method was only used by two teachers (01, 08). The group discussions were not well-organized. The number of students in a group was not consistent, and questions raised for discussion were generic and not well-explained to the students just before the discussion started. Instead, the teachers explained to each group, one by one, what and how the students discuss. Teacher 08 group discussion was not time-bounded. The discussion has gone more than 25 minutes, making the students bored and misbehaving in the class.

Even though every teacher uses a lecture method in their class frequently to explain concepts or give instructions, it was miserable because of teachers' limited English language of communication and content knowledge, for example, teacher 08. Every teacher has difficulty communicating their ideas in the English language, and the problem is severe in some teachers. To overcome this problem, all teachers have been using the Amharic language, not a medium of instruction.

Giving a note was what every teacher had been doing before or at the end of the class. Some teachers waste most of their time on giving notes. Even though most teachers' handwriting was legible, their notes' content was a copy of the textbook. Every student has the textbook individually or in a small group. Giving a note to the students could not be reasonable; rather, it was better if the teachers focused on other activities.

Every grade 7 teacher has been experiencing demonstration methods in their class, except teacher 08. They demonstrated that the acceleration of a body is proportional to the net force applied on the body and inversely proportional to the mass of the body using two different masses, and action force and reaction forces are equal and opposite using two students pushing each other. While teacher 01 was demonstrating in front of the class, activities were not visible to students at the back.

Grade 8 teachers have been using question-and-answering, lecture, problem-solving, and note-giving methods. Similar to grade 7 teachers, they use the lecture method and question and answering method more frequently. Questions were raised at the beginning of the class to check students' understanding of the previous lesson and during lesson development. They used to check whether the students were following the lesson or not and to check their understanding. The questions they raised most of the time were low level. Teachers 03 and 09 probe students' understanding by raising other questions based on students' responses. Teachers 02 and 07 did not comment on students' wrong answers.

In the lecture method, most teachers have difficulty explaining their ideas to students because of their poor English language. In order to overcome this difficulty, they use the Amharic language most of the time. Teacher 07 English language problem was severe. Because of the words he was using and the statements he was constructing, his idea was not clear. The following were some of his statements:

- "All of students' day-to-day activity in the acceleration of motion and place day to days activity presented by uniform acceleration graph."
- "In the large of y-direction when is write down every time where the direction of t it is write down in the time interval the time how to arrangement how to covering by the object at this time".

(07)

In addition to difficulties in his English language, not using Amharic's local language made teacher 07's class the worst. Teacher 03 and 09 explanations were clear and to the point, and they used simple English. Moreover, they have been using Amharic to make the ideas understandable to the students.

In problem-solving, some teachers raised questions that are not clear. For example, teacher 07 said, Find the graph and the area under the curve. This question is grammatically and structurally wrong, and the teacher asked this question without any data or equation given to the students.

Three teachers (02, 04, 07) did not follow clear steps in problem-solving. For example, they draw a graph (a straight line that passes through the origin) and then locate points. Instead, it was better if the teachers locate first the coordinates and then connect the points in the plan and interpret the graph.

Teacher 01 has been giving a problem with the solution, as shown in Figure 4.25, which does not make students think critically and solve problems by themselves, and it also makes them only memorize information rather than working for higher cognitive domains. It was better if the students tried first, or the teacher solved it with students. When a student reads a problem first, he/she thinks of what the given quantities are; What do I compute? And then, which equation should I use to solve the problem? However, when they get a solution, they lack critical thinking, which helps them internalize the concept.

In teacher 05 class a student solved $m = \frac{30N}{5m/s^2} \times \frac{5m/s^2}{5m/s^2}$ as shown in Figure 4.24. The teacher did not ask why the student multiplied by $\frac{5m/s^2}{5m/s^2}$ to probe the conception of the student and why the unit of mass be came $kg\ m/s^2$. The teacher did not understand that reasoning out of each step, in problem solving enhances students understanding.

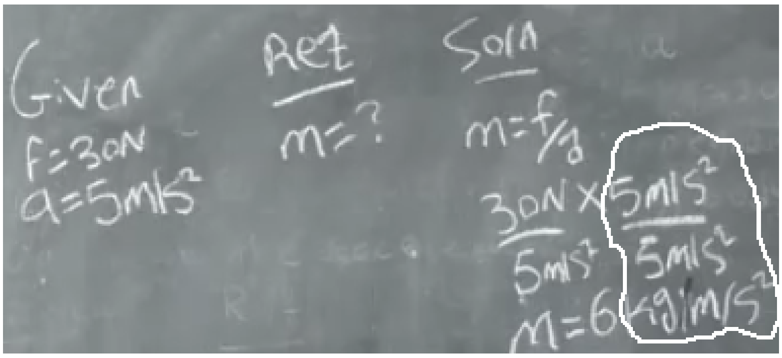


Figure 4.24: Student's steps in solving a problem

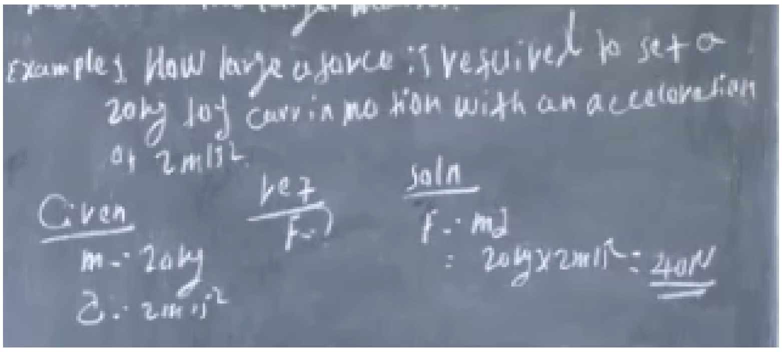


Figure 4.25: Solution given as a note

As shown in Figure 4.9 and Figure 4.10, teacher 04 started his graphical representation of motion by sketching the graphs. If the teacher starts from equations that the students know and generates data and populates the table for motion or starts from tabular data, it will be easy for them to comprehend the idea.

Even though the derivation of the equation of motion was beyond the students' level, the teacher did it with sequential and clear steps that were comprehensible. It was easy for students to drive the displacement equation from the area under the $v-t$ graph for both uniform and uniformly accelerated motion. The teacher can easily demonstrate a slope of $v-t$ graph is acceleration, the slope of $s-t$ graph is velocity, and the area under the $v-t$ graph is displacement.

Teacher 08 award students without correcting or amending students' wrong answers, and she did not make the concepts clear to students. For example, students did not sort contact forces and non-contact forces accordingly. However, the teacher awarded the award without telling or making the idea clear to the students, which leads the students to misconceptions. Maybe the teacher was reluctant to amend students' wrong answers because of her limited knowledge of the difference between contact and non-contact forces.

In general, the methods the teachers have chosen were appropriate. However, the methods were not planned well and lacked sequence and flow. Most teachers from the trained group have well-demonstrated methods they have chosen in their class, while most teachers from the untrained group have not demonstrated well.

Representations including analogies

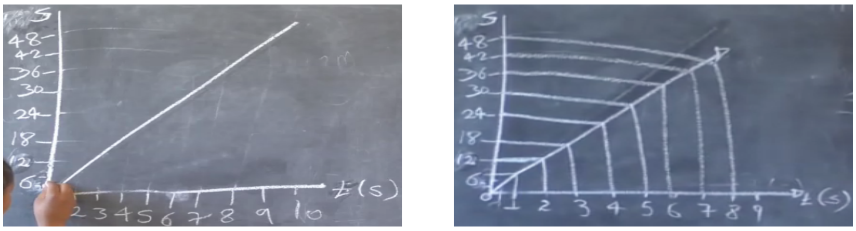
Grade 7, teachers have been using different representations like verbal (text and sound), demo, symbol, mathematical/formula, and diagram. Most of the time were using verbal representations. They have been giving notes on the blackboard and explaining it to the students. Most teachers' explanations were not clear because of their limited English language and content knowledge. Their textual representation was better than others. What they wrote on the blackboard were clear and legible.

Teachers who have been using mathematical representation have well-explained the relation between ideas except teacher 06, who related action force is negative to reaction force and reaction force is positive to action force ($F_A = -F_R$ and $F_R = F_A$). Teacher 08 could not explain the diagram though she used it as a representation. Teacher 01 has well-demonstrated action and reaction forces are equal and opposite by using two students pushing each other in front of the class.

Grade 8 teachers have been using verbal, tabular, graphical, mathematical, and symbolic representations. Even though it was irrelevant, teacher 07 used an analogy for uniform motion. He stated that uniform motion means wearing the same cloth. It seems that uniform motion is the motion of different objects moving with the same velocity. The uniform motion refers to the motion of a body that moves with constant velocity rather than two or more objects with the same velocity.

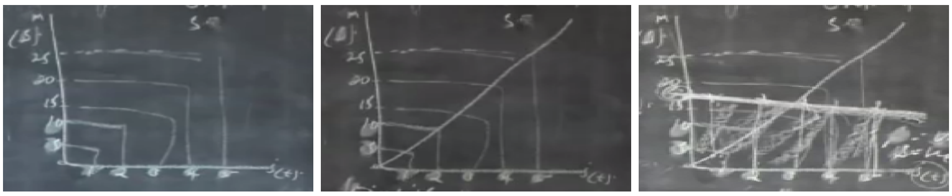
Two teachers (03 and 09), verbal representations were excellent. Their verbal representations convey the real meaning of the concept and are easy to understand. To conceptualize the ideas more, they use the Amharic language in between their English presentation. Every teacher's handwriting was clear and legible except teacher 04, which was not legible.

Teacher 07 did not use tabular representation to plot graphs, which made his work complex and non-understandable. He connected scales on the vertical axis with scales on the horizontal axis and then drew a straight line through the points. It was not clear why he connected the two scales. When he did this, he used neither equation nor tabular data.



(a) *(b)*

Figure 4.26: Teacher 04' graphical representation of uniform motion



(a) $s - t$ *(b)* $s - t$ *(c)* $S - t$ *and* $V - t$

Figure 4.27: Teacher 07's graphical representation of uniform motion

Teacher 04 and 07 graphs were not clear, especially teacher 07 plots two graphs ($v - t$ and $s - t$) on the same plane, which made students confused. Teacher 07 lacks the skill of drawing straight lines. These made the two teachers' work more disgusting, as shown in Figure 4.26a and Figure 4.26. Every teacher had used mathematical representation in plotting graphs and interpreting graphs, and their mathematical equations were represented symbolically.

Every grade 8 teacher lacks, in their class, already prepared graphical representations (such as a graph chart). It helps to save their time in demonstrating an accurate graph , plotted on well-scaled axes, and motivating students.

Most of the time, teacher 06's ideas were fragmented. She started an idea, and then, without completing it, she jumped to another one. The teacher demonstrated well how the unit of force, N, is related to mass and acceleration units: $N = kgm/s^2$. She started from the equation $F = m \times a$ and substitute the units of mass and acceleration in the equation. This helps the students to conceptualize easily, $Newton$ is the product of kg and m/s^2.

Teacher 04 started that the $s - t$ graph of uniform motion is a straight line curve. The teacher drew the graph without any tabular data, as shown in figure Figure 4.9 . It is better if a teacher starts from a tabular representation or mathematical representation and then plots the graph based on the tabular data or equation to enhance students' understanding.

Teacher 07 graphs were not neat. Multiple variables (velocity and distance; and displacement and acceleration) were sketched on the same plane as shown in Figure 4.14c and Figure 4.16b respectively. The ways the teacher plots the graphs were not clear to the students, and his graph was not neat. When the teacher asked students to plot a graph, he did not give them the necessary data or equation required. The teacher's presentation has no smooth flow. In general, teacher 07 has no adequate knowledge and experience to plot a graph and has not chosen appropriate representation to compute displacement for uniform motion and uniformly accelerated motion in grade 8. He has chosen the analytic method, which is beyond the students' level.

Teacher 07 has been using the same plane used for the $s - t$ graph, as shown in Figure 4.14c. At this level, it is difficult to identify the two variables on the same axis.

Table 4.17 quantifies teachers' PCK observed in the classroom using the guidelines (Appendix A.3) Table 4.17 quantifies teachers' PCK observed in the classroom using the guidelines (Appendix A.3). As shown in Table 4.17, students' prior knowledge varies from 1 to 3; curricular salience 1.5 to 3; knowledge of what is difficult to teach 1 to 3; knowledge of representation 1.5 to 3; and knowledge of teaching strategy 1 to 4. When the average of components of teachers' PCK compered between teachers who have the training and have no training on DT: knowledge of students' prior knowledge of the trained teacher is 2.3, and untrained teacher is 1; knowledge of curricular saliency

Table 4.17: Quantifying teachers PCK observed in classroom

Grade	Trained	Teachers	Students' prior knowledge	Curricular saliency	What is difficult to teach?	Repres- entations	Teaching strategy	Average
7	Yes	01	1.0	2.5	1.0	3.0	2.5	2.0
	No	05	1.0	2.5	1.0	1.5	1.5	1.5
	No	06	1.0	2.5	1.0	1.5	2.0	1.6
	No	08	1.0	1.5	1.0	1.5	1.0	1.2
8	Yes	02	2.0	1.5	1.0	1.5	1.5	1.5
	Yes	03	3.0	3.0	3.0	2.5	3.0	2.9
	No	04	1.0	3.0	1.0	1.5	1.5	1.6
	No	07	1.0	2.0	1.0	1.0	1.0	1.2
	Yes	09	3.0	3.0	3.0	3.0	4.0	3.2
Average		All	1.6	2.4	1.4	1.9	2.0	1.9
		Trained	2.3	2.5	2.0	2.5	2.8	2.4
		Untrained	1.0	2.3	1.0	1.4	1.4	1.4

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

of the trained teacher is 2.5, and untrained teacher is 2.3; knowledge of what is difficult to teach of the trained teacher is 2, and untrained teacher is 1; knowledge of representation of trained teacher is 2.5, and untrained teacher is 1.4, and knowledge of teaching strategy of the trained teacher is 2.8, and untrained teacher is 1.4. All untrained teachers could not indicate what is difficult to teach in grades 7 and 8 physics.

These indicate that in each component of the teacher's PCK, as other data from teachers' CoRes and lesson plan have indicated, teachers who have training on DT have better demonstrated their PCK on teaching SCPS physics than untrained teachers. Therefore, training on DT has a positive impact on teachers PCK. Next, teachers' components of PCK explained.

4.5.5 Teachers' PCK as manifested in Questionnaire

In the teachers' questionnaire (Appendix C), item 1 to 10 comprises three questions. The two questions (b and c) intended to probe three of the five components of TSPCK: teachers' knowledge of students' prior knowledge, conceptual teaching strategy, and representations, including analogy. Therefore, in this section, the three components of teachers' TSPCK are explored based on teachers' responses to the ten items.

4.5.5.1 Teachers response to PCK questionnaire

According to teachers' responses to items 1b and 1c, the teachers intended to use two methods: demonstration and lecture method. Procedures in the strategies were not explained very well. Their demonstration intended to apply force on an object to move the object, which may not make the concept clear to the students. One can make the idea clear by demonstrating that a moving object can stop and an object at rest can be set into motion by applying external unbalanced force and making the students aware of the existence of friction force, which makes an object stop its motion. This friction force is not observable to the students, and when an object stops its motion, it seems the object stops due to the absence of external force. Teacher 04 argues that an object stops its motion because of the frictional force between the object and the surface. In the lecture method, the teachers' procedures were not clear to the students. Teachers have chosen two representations: verbal and a demo, to make the idea clear.

Every teacher did not identify the misconceptions. Some teachers argue that there is no misconception (02, 04, 05, 06). Other teachers identified as misconceptions were not clear and irrelevant. For example, teacher 01 identified religion as the cause of the misconception, but she did not mention how. Teacher 08 argues that there is a gravitational force in addition to the applied force, and the concept of action and reaction forces are not well–defined. Therefore, all teachers from both groups (trained and untrained) have no understanding of the idea's misconceptions.

According to teachers' responses to the items 2b and 2c, all teachers, except teacher 03 and 09, did not provide strategies they intended to use in making the idea clear to the students. The two teachers (03, 09) intended to make the concept clear by defining and describing both uniform and uniformly accelerated motion and plotting the $v-\mathrm{t}$ graph and explaining the graph. Except for two teachers (05, 06), all teachers provided representations they intended to use. These indicate that trained teachers have demonstrated better strategies than untrained teachers.

Four teachers (02, 05, 06, and 08) did not identify the misconception. Two teachers argue the misconceptions are students assume $v-\mathrm{t}$ graphs are identical for uniform motion and uniformly accelerated motion (03). Uniform motion and uniformly accelerated motion were not clearly defined to the students (09). Two teachers (04 and 07) did not identify clearly. In general, most teachers were not aware of the misconception that students think that the $v-t$ graph for both uniform motion and uniformly accelerated motion is the same. When we compare trained and untrained teachers, trained teachers have better-identified misconceptions than untrained teachers.

According to teachers' responses to the item 3b and 3c, what all teachers intended to use were not clear or irrelevant to make the idea clear to the students. This idea can be made clear from Newton's second and third laws of motion. From Newton's third law, the two forces the Earth and the object exert on each other are equal in magnitude. Using Newton's second law, it is possible to demonstrate that the Earth's acceleration toward the object is negligible. Therefore, a teacher can make the concept clear by using Newton's second and third laws' mathematical representation. Teachers can demonstrate that the acceleration of the Earth is negligible relative to the object's acceleration because of the large mass of the Earth and a tiny mass of the object around the Earth.

Three teachers (05, 06, 09) did not provide possible students with misconceptions. Except for teacher 03, other teachers' responses were irrelevant or not clear. Teacher 03 from a trained group argues that the students consider no gravitational force by an object around the Earth that acts on the Earth. Some students assume that Newton's third law does not work for the Earth's gravitational force and the object around the Earth.

According to teachers' responses to the item 4b and 4c, the teachers intended to use the lecture method and use graphical and tabular representations. They argue the idea can be clear by explanation. However, only teacher 09 provided a clear procedure in explaining the idea. He intended to give velocities of different objects and compute each object's acceleration and explain each acceleration.

Five teachers (02, 04, 05, 06, 07) did not identify possible misconceptions; three teachers (01, 08, 09) provided an irrelevant response; and teacher 03 identified that if the velocity of an object changes, its acceleration also changes, and acceleration is proportional to velocity. These indicate that there were teachers from the trained group who identified and explained strategies used to make the idea clear to the students. Moreover, most teachers from the untrained group could not identify misconceptions.

According to teachers' response to item 5b and 5c, all teachers intended to use demonstration and/or lecture methods. In the demonstration method, students push an object, and then the teachers explain the two actions and reaction forces are opposite and equal in magnitude and acts on different objects. Therefore, they intended to use verbal, demo, and exemplary representations. The strategies chosen were relevant to both groups, but both of them did not explain their strategies.

Four teachers provided the misconceptions: students assume a large object exerts a greater force than a small object (01), and action and reaction forces act on the same object (03, 04, 09). Two teachers' (07, 08) responses were irrelevant or not clear, and three teachers (02, 05, 06) argue there is no misconception. Some teachers identified misconceptions from both groups, and others did not identify misconceptions.

According to teachers' responses to items 6b and 6c, every teacher intended to use lecture method except for teacher 06. Teacher 06 intended to use the group discussion method. They intended to explain the idea; weight is mass times gravitational acceleration; the gravitational acceleration of the Earth is greater than the moon's gravitational acceleration; mass is independent of gravitational acceleration. Teacher 06 intended to explain that the Earth's gravitational force is $9.8m/s^2$, and the gravitational force of the moon is $1.63m/s^2$. She has no concrete understanding of the difference between gravitational acceleration and the gravitational force. Every teacher intended to use verbal representation. The strategies chosen by both groups were the same.

All teachers argue that there is no possible misconception. Students consider mass and weight of a body to be the same and don't differentiate gravitational acceleration and gravitational force like teacher 06.

According to teachers' responses to item 7b and 7c, all teachers intended to use the lecture method, but most of them did not make explicit their teaching procedure.

Teacher 05 intended to define speed and use mathematical relation $v = s/t$ and at $t = 0$, $S = 0$ and $v = 0/0 = 0$ and teacher 07 intended to show that $0/0$ is 0 and then velocity is zero. The teachers intended to use verbal, mathematical, tabular, and graphical representations. Two teachers' strategy from the untrained group leads students to misconception in computing number over zero.

Except for teacher 03, all teachers did not identify possible misconceptions. Teacher 03 argues that possible misconception arises from dividing a number by zero and the miss-understanding of uniform motion. Similar to teachers' misconceptions, students may forget that average velocity is the ratio of change in position (displacement) to change in time, and they divide displacements with corresponding times. Only one teacher from the trained group has identified students' misconceptions.

According to teachers' responses to item 8b and 8c, the teachers intended to use the lecture method by explaining the concept. Teacher 01 intended to compute total distance and divided by the total time taken; teacher 08 intended to give a note on average velocity and then explain average velocity; teacher 09 intended to define average velocity and compute average velocity. The three teachers did not make explicit how to compute the total displacement from the graph. The main problems observed from teachers' responses were how to compute the total distance from the graph. The teachers from both groups could not explain how to compute displacement from the area under the curve.

Every teacher from both groups did not identify the possible misconception of students. Some possible misconceptions are students consider average velocity as instantaneous velocity, and they think average velocity and uniform velocity are the same.

According to teachers' responses to item 9b and 8c, all teachers intended to use the lecture method. They intended to explain the idea, but most teachers did not show their procedures explicitly. Teacher 05 and 06 intended to use the equation $a = \frac{\Delta v}{\Delta t}$. Teacher 09 intended to explain how to read graphs, then help the students how to determine acceleration from the graph. Every teacher intended to use mathematical representation, and teachers 03 and 09 intended to use graphical representation and mathematical representation. These indicate that all teachers from the trained group have a miss understanding of how to teach motion using the graphical representation, which requires a graph and interpreting graphs rather than only using equations. Some teachers from the trained group have a better understanding.

Five teachers did not identify the possible misconceptions, and what two teachers were identified were not clear. Teacher 03 argues that students consider a straight line for v-t graph, the value of acceleration constant because students misunderstand uniformly accelerated motion. Teacher 09 argues that students' limited knowledge of interpreting graphs is the cause of misconception. He did not identify the misconception.

According to teachers' response to item 10b and 10c, all teachers intended to use lecture and/or demonstration methods. Teacher 02 and 05 intended to explain the idea using the concept of Newton's second law of motion, and teacher 07 argues that velocity is proportional to acceleration, and force is proportional to acceleration, which indicates that teacher 07 has misconceptions about the relation between velocity and acceleration. Acceleration is the time rate of change of velocity rather than it is proportional to the velocity. Representations the teachers intended to use were mathematical, diagram, demonstration, and example.

Six teachers provided possible students' misconceptions. What three teachers provided were not clear. Teacher 03 argues that students assume velocity and acceleration are different physical quantities, so their direction is different. Teacher 03 has misconceptions. She thinks both velocity and acceleration are the same physical quantities, and they have the same direction. Teacher 08 argues that students assume velocity and acceleration are the same. Other possible students' misconception is that students assume that acceleration is directly proportional to velocity, then they have the same direction. Therefore, the two groups have not well-identified students' misconceptions.

4.5.5.2 PCK as demonstrated in Teachers' Questionnaire

Students' Prior Knowledge

Almost all teachers did not identify possible students' misconceptions about each idea.

Most misconceptions provided were either not clear or irrelevant. In contrast, some teachers themselves have misconceptions about the ideas.

Misconceptions identified were in item 2, students assume $v-t$ graphs for uniform motion and uniformly accelerated motion are the same (05, 06); in item 3, students consider an object around the Earth's surface does not exert a gravitational force on the Earth. (03); in item 4, students assume that if an object's velocity changes its acceleration, its velocity also changes. Therefore, acceleration is proportional to velocity (03). In item 5, students assume large weight objects exert a greater force on small weight objects (01). In item 7, students assume dividing a number by zero is zero (03). In item 9, students assume if the $v-t$ graph is straight, then acceleration is constant (03). In item 10, teacher 03 himself assume velocity and acceleration the same physical quantity, so their directions are the same.

Representations including analogies

Representations the teachers intended to use were verbal, mathematical, graphical, tabular, and/or diagrammatic. Their representations were appropriate, but they lack multiplicity. Most teachers intended to use verbal representation from both groups.

Conceptual Teaching Strategies

Responses to the ten items revealed that teachers intended to use lecture and/or demonstration methods in making the ideas clear in all items. Most teachers did not make clear strategies they had chosen. Few teachers made their strategies clear for some items. For an idea in item 5, most teachers intended a student to push an object and then explain the action and reaction forces between the student and the object. For an idea in item 6, most teachers intended to use the equation, $w = mg$, and explain the gravitational acceleration on the Earth is greater than the gravitational acceleration on the moon. Therefore, the weight of the same object on the Earth's surface is higher than on the surface of the moon.

For idea in item 7 teacher 05 and 07 intended to define speed and use mathematical relation $v = S/t$ and at $t = 0$ velocity $v = 0/0 = 0$. Even though the procedure they intended to follow looks clear, the teachers have misconceptions about computing average velocity. To find average velocity, they divided position (distance) with the corresponding time, given in the table. They forgot the definition of average velocity, which is the change in position (displacement) to change in time. Moreover, the teachers have a misunderstanding of a number divided by zero.

For item 8, teachers 01 and 09 intended to compute average velocity. However, they did not mention how to find the motion's total displacement, which needs computing the area under the $v-t$ graph. For item 09, teachers 05 and 06 intended to use the equation $a = \frac{Deltav}{\Delta t}$ to explain the idea. However, this item intends to enable students to compute acceleration from the $v-t$ graph. For item 10, teachers 02 and 05 intended to explain the idea using Newton's laws of motion, and teacher 07 intended to explain velocity is proportional to acceleration. This leads students to misconceptions. The teacher has forgotten that acceleration is the time rate of change of velocity. In general, the teachers intended to make their class teacher-centered, and they did not make their procedures explicit. When we compare the two groups, there was no difference between them in making their strategies explicit. They could not elaborate on their strategies.

Table 4.18: Quantifying teachers PCK as manifested in teachers questionnaire

Grade	Trained	Teachers	Students' prior knowledge	Repres-entations	Teaching strategy	Average
7	Yes	01	1.5	2.0	2.0	1.8
	No	05	1.0	2.0	1.5	1.5
	No	06	1.0	2.0	1.0	1.3
	No	08	1.0	1.5	1.0	1.2
8	Yes	02	1.0	2.0	1.5	1.5
	Yes	03	3.0	2.0	2.0	2.3
	No	04	1.1	2.0	1.0	1.4
	No	07	1.0	1.0	1.0	1.0
	Yes	09	1.5	2.0	2.0	1.8
Average		All	1.3	1.8	1.4	1.5
		Trained	1.8	2.1	1.9	1.9
		Untrained	1.1	1.7	1.1	1.3

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

Table 4.18 shows a quantified summary of teachers' PCK as manifested in teachers' questionnaires, using the guidelines (Appendix A.3). Components of teachers' PCK vary from 1(limited) to 3(developing) for students prior knowledge and from 1(limited) to 2(basic) for representation and teaching strategy. When the average of components of teachers' PCK compered between teachers who have the training and have no training on DT: knowledge of students' prior knowledge of the trained teacher is 1.7($\approx$ basic), and untrained teacher is 1(limited); knowledge of representation of trained teacher is 2(basic) and untrained teacher is 1.7($\approx$ basic); knowledge of teaching strategy of the trained group is 1.8($\approx$ basic), and the untrained group is 1.1(limited). These indicate that in each component of teachers' PCK, teachers who have training in DT have better manifested their PCK. Therefore, training on DT has a positive impact on teachers PCK. Next, teachers' components of PCK were explained, how they elaborated in their response to the questionnaire.

4.5.6 Summary

This subsection summarizes and triangulates the PCK demonstrated in the four instruments: CoRe, lesson plan, classroom observation, and questionnaire.

Table 4.19: Average of quantified teachers' PCK using four instruments

Instrument	Teachers	Students' prior knowledge	Curricular saliency	What is difficult to teach?	Repres-entations	Teaching strategy	Average
CoRe	All	2.3	1.9	2.6	2.2	2.4	2.3
	Trained	2.8	2.5	3.0	2.3	2.8	2.7
	Untrained	2.0	1.4	2.2	2.2	2.2	2.0
Plan	All	1.2	1.6	1.0	1.9	2.1	1.5
	Trained	1.2	1.9	1.0	2.4	2.6	1.8
	Untrained	1.1	1.3	1.0	1.5	1.7	1.3
Observation	All	1.6	2.4	1.4	1.9	2.0	1.9
	Trained	2.3	2.5	2.0	2.5	2.8	2.4
	Untrained	1.0	2.3	1.0	1.4	1.4	1.4
Questionnaire	All	1.3			1.8	1.4	1.5
	Trained	1.8			2.1	1.9	1.9
	Untrained	1.0			1.7	1.1	1.3
Average	All	1.6	2.0	1.7	2.0	2.0	1.8
	Trained	2.0	2.3	2.0	2.3	2.5	2.2
	Untrained	1.3	1.7	1.4	1.7	1.6	1.5

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

Tables (4.15, 4.16, 4.17 and 4.18) indicate that SCPS physics teachers best portrayed their PCK in teachers' CoRes than other instruments used: In CoRe 2.3, in plan 1.5, in-classroom observation 1.9 and in questionnaire 1.5. Even though the teachers were more familiar with preparing a lesson plan, they did not demonstrate their PCK in their lesson plan as expected. These indicate that the teachers have been preparing lesson plans to obey the regulation of their school rather than for use in their class. Teachers' PCK portrayed more in their CoRes than in their classroom, which indicates that the teachers could not demonstrate, in their class, what they know, in a comprehensible manner. From the average of the PCK demonstrated in four instruments, as shown in 4.19, teachers who have training in DT have better demonstrated their components of PCK in each instrument than teachers who have no training. The average of all teachers' components of PCK observed in each instrument varies from 1(Limited) to 2(Basic). These show that the teachers' PCK is not well developed.

Table 4.20: Average of each teacher's components of PCK

		Components of PCK					
Trained	Teacher	Students' prior knowledge	Curricular saliency	What is difficult to teach?	Repres-entations	Teaching strategy	Average
Yes	01	1.5	1.8	1.3	2.4	2.3	1.9
	02	1.8	1.3	1.7	1.9	1.5	1.6
	03	2.5	3.0	2.3	2.4	2.6	2.6
	09	2.1	3.0	2.7	2.4	3.5	2.7
No	05	1.8	2.0	1.7	2.1	2.3	2.0
	06	1.3	1.7	1.3	1.5	1.4	1.4
	08	1.0	1.2	1.7	1.8	1.5	1.4
	04	1.4	2.2	1.3	2.0	1.8	1.7
	07	1.0	1.3	1.0	1.1	1.1	1.1

Note: 1 = Limited, 2 = Basic, 3 = Developing and 4 = Exemplary

Table 4.20 shows average of each teacher's PCK and average of components of each teacher's PCK observed in the four instruments. Average of teachers PCK varies from 1.1 (limited) to 2.7 ($\approx$ Developing). The highest achiever is from the trained group and the least achiever is from the untrained group. Teachers' students prior knowledge varies from 1(limited) to 2.5($\approx$ developing); curricular salience from 1.2($\approx$limited) to 3(Developing), what is difficult to teach from 1(limited) to 2.7($\approx$ Developing); representations from 1.1($\approx$ limited) to 2.5 ($\approx$ developing) and teaching strategies 1.1 ($\approx$ limited) to 3.5 ($\approx$exemplary). When we compare components of teachers' PCK for each teacher, they have demonstrated their components of PCK consistently.

4.6 Comparative Analysis of Implementation of DT in Physics Class with respect to Training on DT and Knowledge Domains

In this section, implementation of dialogic teaching (section 4.2) is comparatively analysed with respect to:

1. Training on Dialogic Teaching (section 4.2) and
2. Teachers' knowledge Domains (CK (section 4.3), PK (section 4.4) and PCK (section 4.5))

4.6.1 Comparison based on Training on DT

In this section, the implementation of DT in teachers who have trained on DT and who have no training in DT were compared. The comparison was based on a summary of the analysis of DT given in Table 4.3. The trained teachers on DT were Teacher 01, 02, 03, and 09, and those who had no training on DT were Teacher 04, 05, 06, 07, and 08. Alexander (2008)'s five features/principles of DT were used to compare the two groups. Each feature of DT was analysed and ranked into No DT, partial DT and full DT. Table 4.21 and Figure 4.28 show frequency table and bar graph for teachers' implementation of each feature of DT in their classes.

Table 4.21: Comparison between Trained and Untrained Teachers

	Trained						Untrained					
Imple.	Collective	Reciprocal	Supportive	Cumulative	Purposeful	Average	Collective	Reciprocal	Supportive	Cumulative	Purposeful	Average
No	1	2	2	1	0	1	2	5	5	4	1	4
Partial	3	2	2	3	1	3	3	0	0	1	4	1
Full	0	0	0	0	3	0	0	0	0	0	0	0

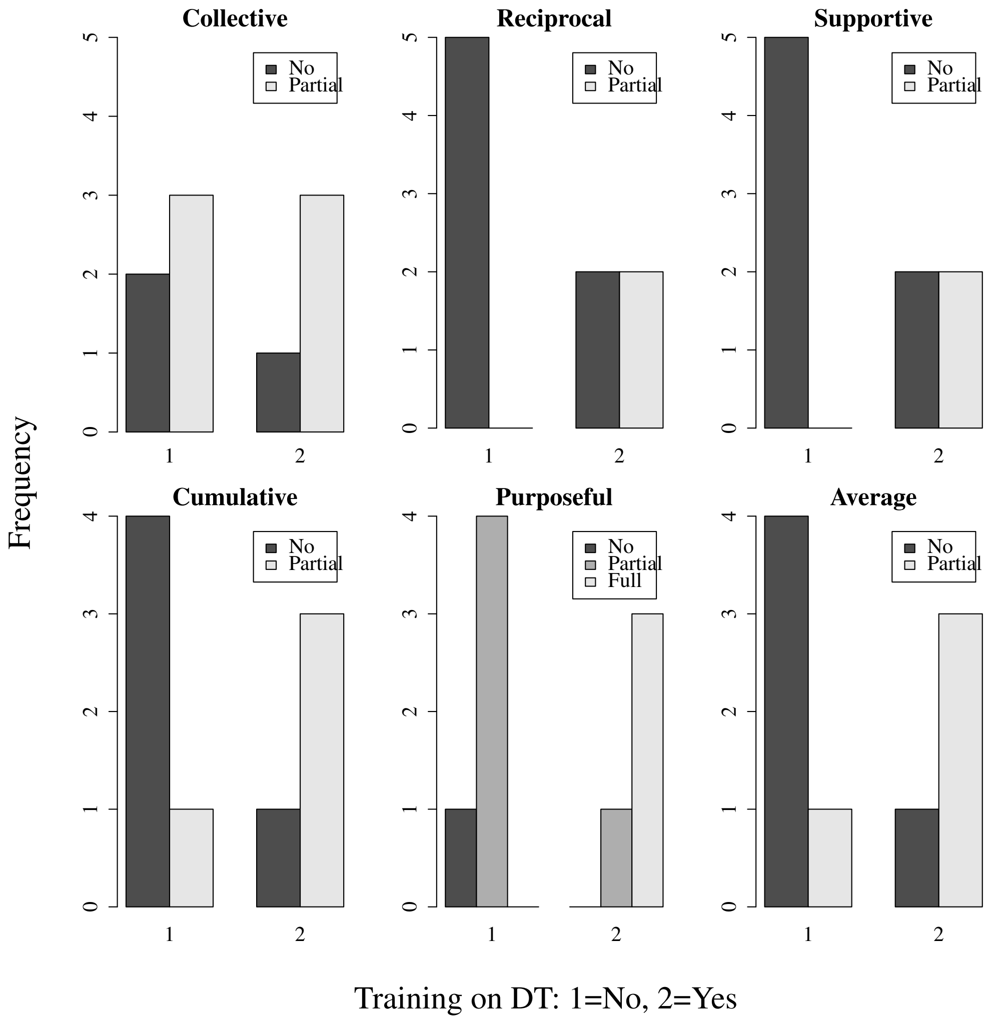


Figure 4.28: Comparison of DT with respect to Training On DT

The table and the bar graph show that more proportion of trained teachers have demonstrated all features of DT more than untrained teachers.

Even though trained teachers have better-demonstrated features DT, according to Alexander (2008), both trained and untrained groups did not demonstrateDT in their class. Alexander (2008) argues that unless a classroom talk meets the five principles of DT, it is not dialogic. As shown in Table 4.21 and Figure 4.28 except a purposeful feature of DT all features were not fulfilled in every class. So that DT was not demonstrated by the participating teachers.

4.6.2 Comparison based on Knowledge Domains

In this subsection, teachers' implementations of DT are compared with respect to each component of Knowledge domains. As shown in Table 4.22, three teachers (03, 05 and 09) CK were greater than average and six teachers (01, 02, 04, 06, 07 and 08) were less than average; four teachers (03,04, 05 and 09) PK were greater than average and five teachers (01, 02, 06, 07 and 08) were less than average; and two teachers (03 and 09) PCK were greater than average/basic and seven teachers were less than average/basic. When we compare the overall average of teachers' KDs with respect to training on DT, trained teachers' average was greater than partial, and untrained teachers' average was less than partial. This indicates that training on DT has an impact on teachers' knowledge domains.

Table 4.22: Teachers Knowledge domain

		Trained Teacher				Untrained Teacher					
KDs	Instrument	01	02	03	09	04	05	06	07	08	Ave.
CK	Observation	25	50	88	88	25	75	38	0	0	43
	Questionnaire	44	22	67	67	44	56	56	33	14	45
	Average	35	36	78	78	35	66	47	17	7	44
PK	Observation	50	25	75	83	58	50	25	25	25	46
	Questionnaire	58	67	67	75	75	67	58	58	58	65
	Average	54	46	71	79	67	59	42	42	42	56
PCK	CoRe	65	50	65	85	60	80	35	25	50	57
	Plan	35	38	58	53	35	38	33	30	30	39
	Observation	50	38	72	80	40	38	40	30	30	46
	Questionnaire	38	38	58	46	34	38	33	25	29	38
	Average	47	41	63	66	42	49	35	28	35	45
Over all average		46	41	69	72	46	55	40	28	30	47
			57					40			47

Next, teachers' implementations of DT were compared with respect to each component of the teacher's knowledge domains: content knowledge, pedagogical knowledge, and pedagogical content knowledge. Also, their implementations were compared with respect to their misconception in Newton's laws of motion and graphical representation of motion. Frequency tables and bar graphs were used to compare teachers' implementation of DT.

Table 4.23: Frequency table of DT with respect to teachers Knowledge Domains

DT		Components of Teachers' Knowledge Domains					
		CK		PK		PCK	
Feature	Impele.	$< average$	$\geq average$	$< avereage$	$\geq basic$	$< basic$	$\geq basic$
Collective	No	2	1	2	1	2	1
	Partial	4	2	3	3	5	1
	Full	0	0	0	0	0	0
Reciprocal	No	6	2	0	3	7	1
	Partial	0	1	5	1	0	1
	Full	0	0	0	0	0	0
Supportive	No	6	2	5	3	7	1
	Partial	0	1	0	1	0	1
	Full	0	0	0	0	0	0
Cumulative	No	4	2	4	2	5	1
	Partial	2	1	0	2	2	1
	Full	0	0	1	0	0	0
Purposeful	No	1	0	1	0	1	0
	Partial	4	1	3	2	5	0
	Full	1	2	1	2	1	2

Frequency Table 4.23 compares implementation of DT with respect to each teachers' Knowledge domains; bar graphs in Figure 4.29, Figure 4.30 and Figure 4.31 compare implementation of DT with respect to teachers content knowledge, pedagogical knowledge and pedagogical content knowledge respectively.

The bar graph in Figure 4.29 shows that except for a collective feature, in all features of DT more proportion of teachers whose content knowledge greater than $average$ was better demonstrated than teachers whose content knowledge was less than $average$.

This shows the four features of DT are positively affected by teachers' content knowledge. In collective feature of DT the two groups (Content knowledge $\geq average$ and $< average$) have demonstrated with equal proportions.

The average of DT on the right and bottom shows that more proportion of teachers whose CK is greater than average have better-demonstrated DT.

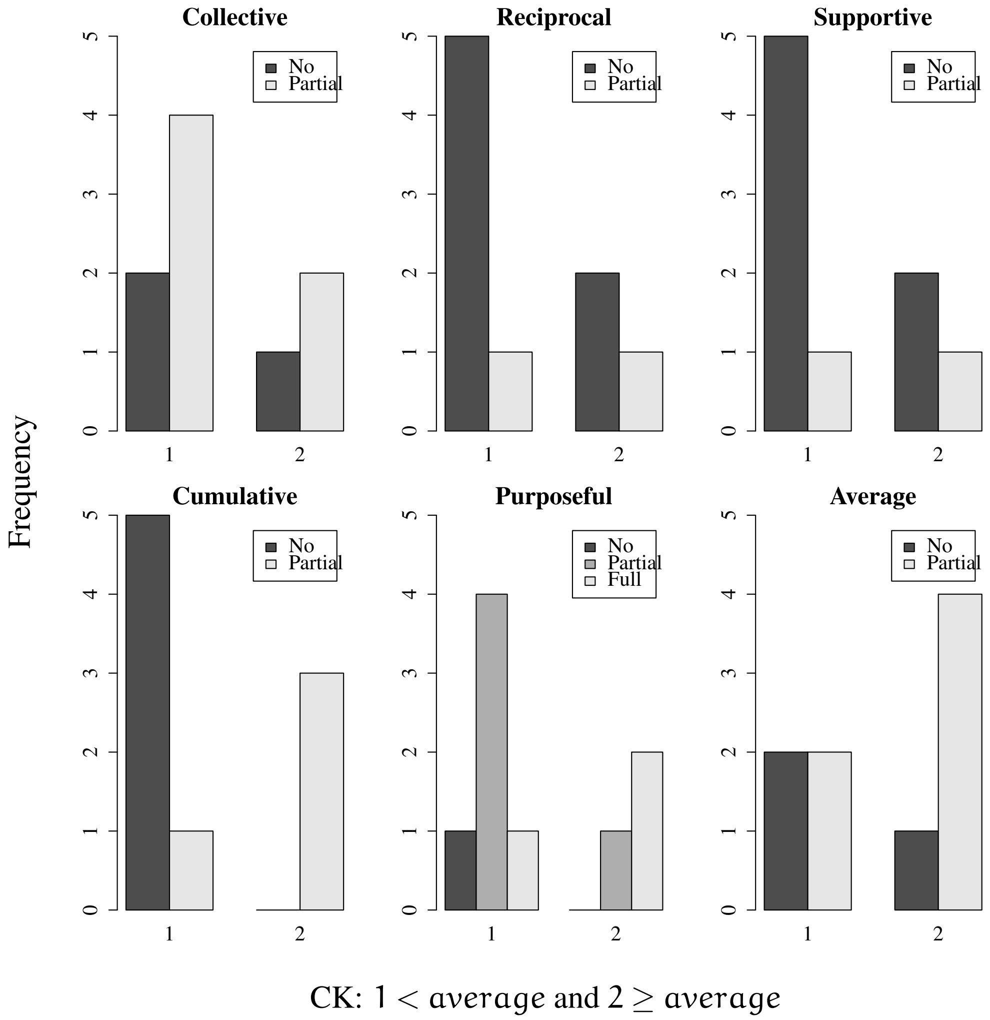


Figure 4.29: Comparison of implementation of DT with respect to content knowledge

The bar graph in Figure 4.30 shows in all features of DT more proportion of teachers whose content knowledge greater than $average$ were better demonstrated than teachers whose CK were less than $average$. This shows the five features of DT are positively affected by teachers' pedagogical knowledge. The average of DT was consistent with each feature.

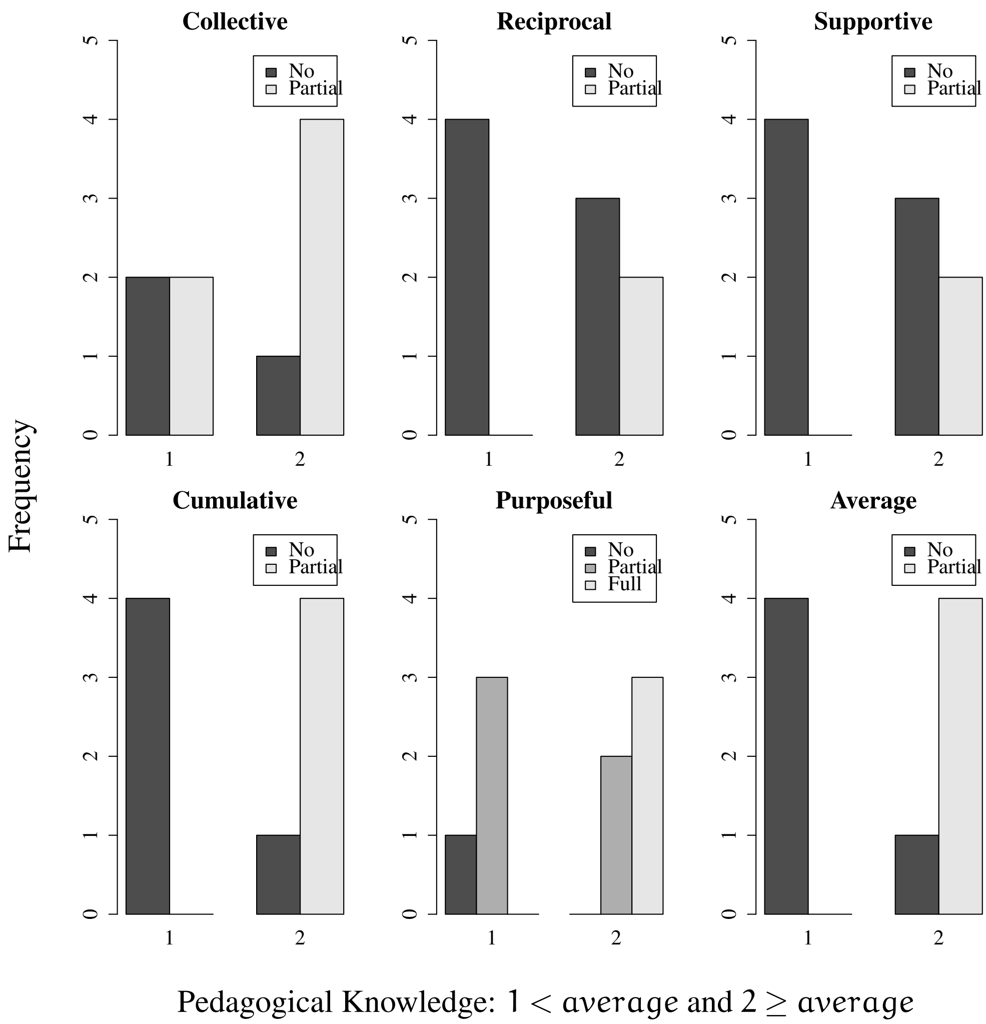


Figure 4.30: Comparison of implementation of DT with respect to pedagogical knowledge

The bar graph in Figure 4.31 shows in all features of DT more proportion of teachers whose content knowledge greater than $average$ were better demonstrated than teachers whose CK were less than $average$. This shows the five features of DT are positively affected by teachers' pedagogical content knowledge. The average of DT was consistent with each feature.

In general, the frequency table and the bar graphs for each KD depict that physics teacher's KDs positively affect the implementation of DT in their physics class.

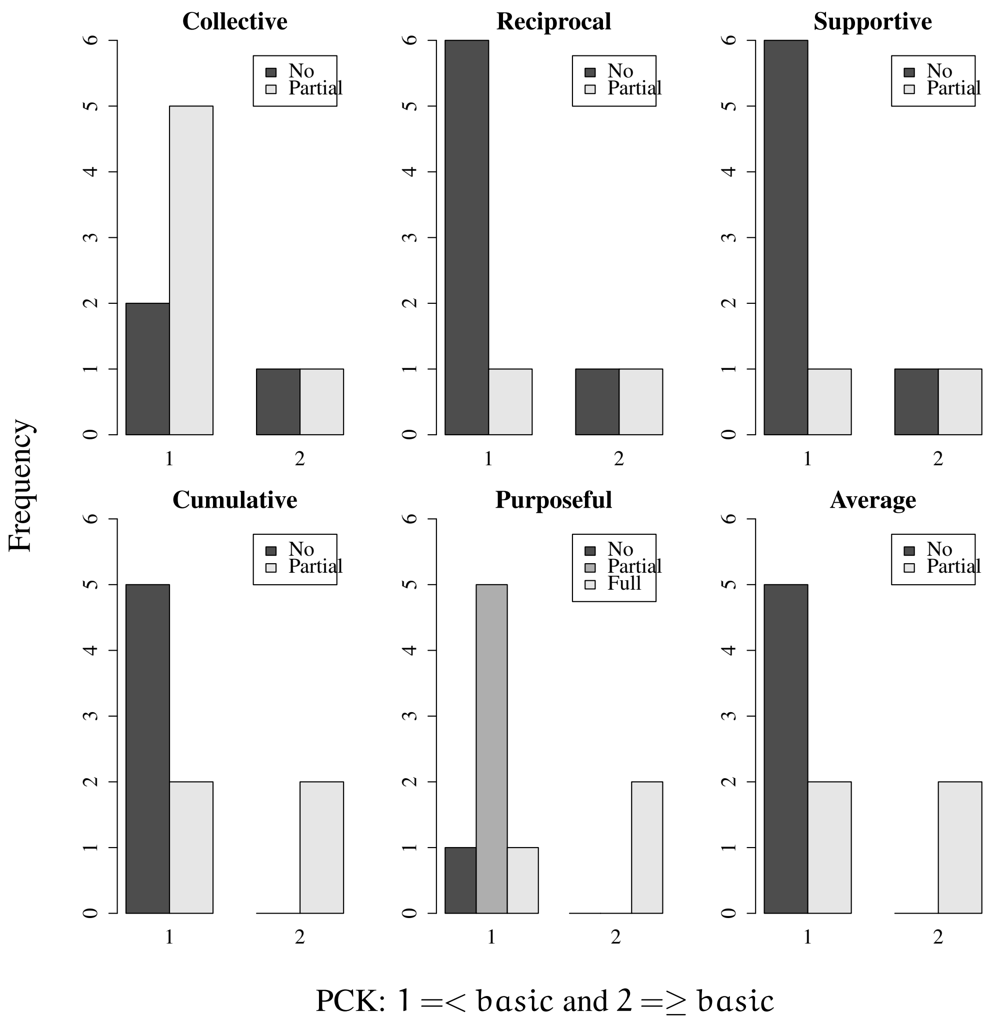


Figure 4.31: Comparison of implementation of DT with respect to PCK

The comparison Table 4.24 of teachers' misconceptions indicates that all teachers have misconceptions about computing average velocity and about uniform motion and uniformly accelerated motion. From eleven teachers' misconceptions identified, teacher 07 has 73 % misconceptions. Trained group has 38.6 % misconceptions while untrained group has 47.27 % misconceptions. This indicates that untrained teachers have greater misconceptions than trained teachers.

Table 4.24: Teachers misconceptions

No	Misconceptions or Misunderstandings	Dialogic Teaching									Total
		Trained				Untrained					
		01	02	03	09	04	05	06	07	08	
1	Inertia	√			√		√		√	√	5
2	Newton's first law							√		√	2
3	Newton's third law	√	√				√	√			4
4	Gravitational force and gravitational acceleration							√	√		2
5	Computing average velocity and average acceleration from tabular data	√	√	√	√	√	√	√	√	√	9
6	Equations of displacement for uniform motion and uniformly accelerated motion								√		1
7	Lifting an object is not applying a force	√									1
8	Number over zero is zero		√						√		2
9	Plotting and interpreting graphs			√		√			√	√	4
10	Differentiating uniform motion and uniformly accelerated motion	√	√	√	√	√	√	√	√	√	9
11	Direction of velocity and direction of acceleration	√	√						√	√	4
Total misconception of each teacher in %		55	46	27	27	27	36	46	73	55	43
Average misconception of groups in %		38.6				47.27					43

4.7 Discussion of Result

4.7.1 Dialogic teaching

According to Alexander (2008), if a classroom talk does not meet the five features (principles) of DT, it is not dialogic. Dialogic teaching is rare and difficult to achieve in today's schools (Reznitskaya, 2012). It was observed that fulfilling the five principles of dialogic teaching was difficult for the teachers. Therefore, the classes observed were not dialogic. In this section, the five dialogic teaching features in physics teachers' class were analyzed, and the two groups were compared. Teachers who have training on DT have better-demonstrated DT in their class than teachers who have no training, and teachers who have better knowledge domains have also demonstrated DT in their class than those who have lower knowledge domains. Each feature of dialogic teaching in the class was discussed as follows.

Collective

In a dialogic class, teachers and students address learning tasks together (Alexander, 2008). In a few teachers' classes, especially from the trained group, there was good student participation. The students' participation was mainly lead by teachers. The contribution of students in addressing the learning task was minimal. On the contrary, most teachers' classes, especially from the untrained group, students' participation was not observed. Teachers pose questions, and some students respond to the question or the teacher themselves answer the posed question. Therefore, the classes were more teacher-centered.

In general, in most classes, students' ideas were not reflected; rather teachers' recitation and instructional repertoire of the talk was dominant. Students' ideas were not reflected. Except in a few teacher's classes from a trained group, students were not encouraged to reflect their idea.

Therefore, dialogic teaching's collective nature was superficial in a few teacher's classes and other teachers' classes, and it was authoritative. The teachers were dominant in their class, and students had no responsibility, and their explanation, narration, and questions were almost absent.

From comparative analysis based on training in DT result (see subsection 4.6.1), it has indicated that collective features of DT are partially demonstrated, in physics teachers' classes who have training on DT. On the other hand, comparative analysis held based on teachers' CK result (see subsection 4.6.2), has indicated that the same proportion of teachers who achieved $\geq$ average and $<$ average have the same proportion in partial implementing DT in their class. In the other two components of teachers' knowledge domains, more teachers who achieved $\geq$ average or basic have better implemented than teachers who achieve $<$ average or basic.

Reciprocal

In a dialogic class, teachers and students listen to each other, share ideas, and consider alternative viewpoints (Alexander, 2008). Even though a few teachers from the trained group look for alternative ideas and extend the discussion, most teachers from both trained and untrained groups look for the correct answer. The teachers did not relate students' answers to each other. Most teachers did not encourage students to support or refute other students' ideas. Rather they asked other questions or continue their discussion without students coming to a common understanding or teachers summarize the idea authoritatively. There were no contesting ideas reflected among students. There were classes in which students did not listen to their teachers and their peers.

In Dialogic class, "the teacher does not miss opportunities to make visible connections among student ideas and prompt students to relate their ideas to others' ideas. He or she often attributes student ideas and questions to specific speakers." (Reznitskaya, 2012). Therefore, the classrooms lack the reciprocal feature of dialogic teaching in every teacher's class except for two teachers, which were partial. Comparative analysis results (see subsection 4.6.1 and subsection 4.6.2) have shown that more proportion of teachers who have training on DT and who have achieved $\geq$ average have partially better demonstrated than teachers who achieved < 50 average in each component of their Knowledge domains.

Supportive

In dialogic class, students articulate their ideas freely, without fear of embarrassment over 'wrong' answers; and they help each other to reach common understandings (Alexander, 2008).

Even though students have no fear of embarrassment, in their wrong answer, some teachers discourage students in a few classes. For example, while a student answers a question, the student went out of the day's topic, and the teacher commanded, "stop.", this discourages students not to be engaged in activities.

During the group discussion, in a few teacher's classes, some teachers were moving among the students and steering the discussion and giving a chance to students who were reluctant to answer questions because of their shyness. Most teachers, especially from the untrained group, the feedback was non-informative and non-discriminating.

Some teachers asked numerous questions at a time without sufficient waiting time, this does not help students to think aloud, and it invites memorization. There were teachers, from the untrained group, who spoke to the blackboard while giving notes. It made students not see the teacher's body language, and instead of following the teachers, the students were tied to note-taking. There were students in some classes who were idle during problem-solving. In most classes, students did not ask questions and provided explanations, and they are not encouraged to do so. Therefore, most classes lack the supportive feature of dialogic teaching.

As indicated in comparative analysis results (see subsection 4.6.1 and subsection 4.6.2), supportive features of DT were more demonstrated in teachers classes who have training in DT than who have no training. Also, most teachers who achieved $\geq$ average, better-demonstrated DT in their classes than those who achieved $<$ average.

Cumulative

In a dialogic class, teachers and students build on their own and each other's ideas and chain them into coherent lines of thinking and enquirer (Alexander, 2008). The discussion centers on truly open and cognitively challenging questions. The questions target higher-order thinking, involving students in critical evaluation and analysis (Reznitskaya, 2012).

Some teachers raised unstructured and ambiguous questions and asked numerous questions at a time. These questions prevent students' participation and could not help students to build their knowledge on their own and others. The questions were not provoking thoughtful answers and did not help students construct their knowledge based on what they know. Students' answers did not provoke further questions. Therefore, teachers' questions and students' answers did not enhance dialogue in the class.

All teachers, especially untrained teachers, ask lower-level cognitive domain and closed-ended questions most of the time, which does not probe the students' understanding. Teachers look for the correct answer, and once a student answered the question, the teacher did not prop for other ideas or comments. The teacher could not work with students' answers to inspire further exploration. The teacher uses short or ambiguous feedback. The feedbacks were not informative and discriminating. The feedback does not invite students further to develop their answers (Reznitskaya, 2012). On the contrary, a large proportion of teachers from the trained group asked questions that can prob students' understanding based on students' responses and help students build their understanding based on their prior knowledge.

After the whole class or group discussion, most teachers did not chain students' ideas, and the students ended their discussion without developing a common understanding. Rather, the teacher tells the students the fact as a summary. Therefore, the cumulative feature of dialogic teaching was not well-demonstrated in the teachers' class.

As indicated in comparative analysis results (see 4.6.1 and 4.6.2), more proportion of trained teachers better demonstrated the cumulative feature of DT than untrained teachers. In teachers' classes who have achieved $\geq$ average or basic in each component of their knowledge domains, they have demonstrated a cumulative feature of DT in more proportion than who achieved $<$ average or basic.

Purposeful

In a dialogic class, teachers plan and steer classroom talk with specific educational goals in view (Alexander, 2008). Every teacher, except three teachers (one from the trained group and two from the untrained group), has been addressing the topics' contents. The two teachers have intruded on content that was out of the topic and beyond the students' level, which did not address the objectives in the syllabus.

During group discussion, to maintain the topic of discussion, most teachers were steering the class or groups very well. A few teachers could not follow their students' activities very well while discussing issues out of the topic. Some teachers allotted more than needed time for classroom discussion; as a result, some students were idle and bored as time went on.

From the trained group, two teachers were well-planned and used their time purposefully. Even though the duration of the time was extremely different, all teachers gave notes on the blackboard. Three teachers (one from trained and two from untrained) have wasted most of their time giving notes. These made them not accomplish the contents they were intended to accomplish. Therefore, from all features of dialogic teaching, this feature is better demonstrated in teachers' classes.

As indicated in comparative analysis results (see subsection 4.6.1 and subsection 4.6.2) purposeful feature of DT was fully demonstrated in teachers who have training in DT than who have no training and in more proportion of teachers class who achieved $\geq$ average or basic in their every component of knowledge domains.

In general, teachers who have trained on DT and who achieved $\geq$ average or basic in their knowledge domains have demonstrated features of DT in their class better than teachers who have no training on DT and who achieved $<$ average or basic in their knowledge domains.

4.7.2 Content Knowledge

Research findings indicate teachers' subject matter knowledge and the number of courses they have taken impact teachers' quality of teaching and students' learning (Cochran-Smith et al., 2008). In this study, the teachers have taken at least basic physics courses in their diploma course work and/or advanced courses in their degree course work. Except for teacher 06, their specialization was in physics. Teacher 06's specialization was in general science. The teaching experiences of the teachers range from 3 to 10 years of teaching.

As it is revealed, in both classroom observation and response to the questionnaire, there were teachers' misconceptions and lack of procedural knowledge. These misconceptions and lack of procedural knowledge were severe in some teachers. The result from both classroom observation and response to the questionnaire were consistent. Similar to Talbert et al. (1993), even though these teachers have had teaching experience greater than three years, most teachers' CK were fragmented, and they were forced to teach algorithms and facts they remember.

Major areas of misconceptions observed by the two instruments were inertia, average velocity, average acceleration, the relation between velocity and acceleration, interpreting a graph, Newton's second law, weight, and gravitational acceleration, dividing a number by zero and Newton's third law.

Some teachers relate inertia with their thinking and argue that if a body is at rest, it has inertia, and if a body is in motion, it has no inertia. Who conceptualized inertia as the cause for a body to stop its motion, or if there is no force applied to a body, it stops its motion.

Similar to studies done by Fadaei & Mora (2015); Poutot & Blandin (2015) on students, SCPS physics teachers have misconceptions about average velocity and average acceleration, and their relation to force. The teachers can compute average velocity if displacement and elapsed time are given and can compute average acceleration if initial velocity, final velocities, and elapsed time are given. However, in computing average velocity, from tabular data, the teachers forgot that average velocity is the ratio of total displacement to the total time elapsed, and average acceleration is the ratio of change in velocity to the total time elapsed (Serway & Vuille, 2014). To compute average velocity, the teachers divide each position with each corresponding time, and to compute average acceleration; they divided each velocity with each corresponding time. Some teachers relate velocity and acceleration as if they had a direct relation. As a result, they assume velocity is proportional to force, and the direction of the velocity of an object is always in the same direction of force and acceleration, which is consistent with the finding of Poutot & Blandin (2015) which was done on high school students. Some teachers conceptualized a number over zero is zero, and could not differentiate gravitational force (weight) and gravitational acceleration. They argue the weight of a body is $9.8m/s^2$.

Some teachers conceptualized that Newton's third law does not work for everybody. They argue that because of the mass of the Earth's magnetic force, the magnitude of gravitational force on an object around the Earth's surface is greater than the reaction force the object exerts on the Earth, which is consistent with Fadaei & Mora (2015), which says great mass implies great force. Some teachers conceptualized that if an object accelerated another object, then the object exerts greater force than the one which is accelerated. Also, a teacher argues that the action force is negative to the reaction force, and the reaction force is positive to the action force. All teachers have no understanding that why an object around the Earth's surface accelerates toward the Earth while the Earth does not accelerate toward the object. There was also a teacher who conceptualized the effects of force as Newton's laws of motion. In general, teachers' misconceptions are severe in some teachers from untrained groups to the extent they may lead students to misconceptions about the contents they were teaching.

4.7.3 Pedagogical knowledge

Using the three instruments (classroom observation, questionnaire, and interview) teachers' PK was explored. Teachers' theoretical understanding of PK was different from their implementation in their classes.

As the teachers respond in the questionnaire, they have a better understanding of classroom management regarding classroom rules, how to motivate students, and how to intervene in minor miss behaviors without distracting them. However, as observed in the classroom, some teachers discourage students, and in every classroom, no classroom rules were posted on the walls, which indicates that the teachers were reluctant to prepare and/or use classroom rules. Also, it was observed most teachers' plans were not satisfactory, and some teachers were autocratic. Students stand up when a teacher enters a classroom. This could not create positive student-teacher relations.

From the teachers' interviews, most teachers had an authoritative view. They believe that a teacher knows everything that he/she teaches. They argue a teacher should not say to his students, I don't know. They think that a teacher knows every concept in a topic he/she is going to teach. Some teachers believe that a student should ask what is not clear to him/her at the end of the teacher's presentation. Because a teacher should use his time efficiently, otherwise, the time allotted is not enough to cover the content, and a student should not distract other students who are following the teacher attentively. These indicate that these teachers mainly focus on content coverage rather than students' understanding. Concepts in science, especially in physics, are interdependent, like chains. If a chain breaks, other chains will be dismantled. Students 'understanding of a concept depends on another concept. For example, it is difficult to understand acceleration without understanding the velocity and time. Therefore, students who did not understand a physics concept that a teacher had thought before also could not understand the next concept, about the teacher, which the teacher is teaching. To avoid this challenge, a teacher should respond to students' questions and give a chance to his/her student to ask what is not clear to them.

The teachers believe that a teacher should use different teaching methods; students learn from their misconceptions and peers; teacher-centered class does not encourage students' extrapolation and does not enhance students' understanding. Whereas in their classes, most teachers did not use more than two methods, and more of the class was teacher-centered. The most frequently used method was the lecture method and the question and answer. Most teachers' questions were low-level and close-ended. Some teachers' questions were not clear or not to the objective. A closed-ended question could not create multiple strong responses, and it does not invite critical thinking. Teachers must seek to encourage creative and critical thinking, not memorization, and no single solution models in a discussion. Open-ended questions permit students to elaborate and think through their answer (Cashin & McKnight, 1986) and help students in discussion (Johnson, n.d.). The lectures were highly fragmented and lacked clarity due to teachers' English and content knowledge.

The teachers believe that a teacher should know his/her students' understanding, background, knowledge level, and learning styles. They argue these help the teacher to decide and choose appropriate teaching methods and help the students (Airasian, 2001). In contrast to their response to teachers' questionnaires, most teachers did not have the skill of assessing their students' understanding during their class. For example, they raised closed-ended questions and did not probe students by asking that ing questions based on their answers. Some teachers have listed the three phases of classroom assessment. However, no one has explained the purpose of each phase.

The teachers have been using three primary data gathering methods: students' product, observation technique, and oral question technique (Airasian, 2001). In the classes, the oral question technique was frequently used by the teachers. The oral questions raised by some teachers were ambiguous, had no waiting time, low level open-ended, and/or more than two questions were asked at a time.

In general, there is a similarity between the two teachers groups (trained and untrained) in their belief and understanding of their pedagogical knowledge. But trained teachers have better demonstrated their pedagogical knowledge in their class.

4.7.4 Pedagogical Content knowledge

Students' prior knowledge and misconceptions

It involves understanding students' prior knowledge or misconceptions about the topic and knowing how to integrate crosscutting concepts within the topic (Mphathiwa, 2016) on Newtons' law of motion and the graphical representation of motion. Students learn more when they can connect what they are learning to what they already know (Ambrose et al., 2010) and a teacher understands his students' difficulties. Therefore, a teacher should know about his students' area of confusion or misunderstanding, otherwise students try to build their knowledge on their wrong conception.

The teachers have provided students with misconceptions and difficulties in the data collected by the two instruments (CoRe and questionnaire). The teachers were different in understanding their students from what they provided. Teachers identified: the velocity-time graph for both uniform and uniformly accelerated motions are the same; an object around the surface of the Earth does not exert a gravitational force on the Earth; if the velocity of an object changes, its acceleration also changes; force and acceleration are not related, as students' misconceptions. The teachers identified: poor English language, lack of interest to learn physics; lack of support from families; lack of background knowledge on a graph; students could not connect what they know with their daily life, as students' difficulties.

In the other two instruments (Classroom observation and lesson plan), the teachers did not identify students' misconceptions and difficulties very well, like the previous instruments. In understanding students' difficulties, two teachers (03, 09) have given a brief explanation of graphs before they start about the graphical representation of motion. The CoRe and questionnaire have revealed students' prior knowledge and misconceptions better than the other four instruments.

Curricular Salience

Curricular salience is based on the content, importance, depth, and contextualization of the topic Mphathiwa (2016). This study includes big ideas on the topics: Newton's law of motion and graphical representation of motion, why the topics are important and sequencing: what to begin with and what to leave out for later when teaching the topic.

In their CoRe's, the teachers have provided contents they intended to teach. The contents were not well-explained. What two teachers, from the untrained group, provided were irrelevant to the topic and lack clarity. For example, teacher 07 stated that " Be attend to students about uniform motion, the object moves to constant speed of on the same speed when constant force applied on the object then ideally." Except teacher 07, grade 8 teachers have provided logical sequences of concepts more than grade 7 teachers. Contents provided in teachers' lesson plans were generic, and the purposes provided were not specific to the topic. For example, they stated that the contents are important in the future at higher grades.

Except for two, grade 8 teachers have raised all contents in the topics they intended to teach. Teacher 01 and 07 did not raise essential concepts in their presentation like the slope of $s-t$ and area under $v-t$ graphs for uniform motion and the slope of $v-t$ in a uniformly accelerated motion.

Some teachers have been teaching contents that are beyond the students' level. For example, deriving equations of motion and plotting displacement time graph for uniformly accelerated motion and plotting acceleration time graph for non-uniformly accelerated motion. That indicates that there are teachers who did not identify contents they should teach at that level. In general, in both groups, there are teachers with limited curricular salience in topics they were teaching.

What makes topic difficult to teach

Through experience, a teacher can identify some factors that make a topic difficult to teach: complex ideas, students' misconceptions, and classroom context. In their CoRes, the teachers have provided what makes the topics difficult to teach: limited resources, difficult and complex concepts, and contextual problems. All teachers did not give reasons why they make the topic difficult to teach. For example, the country's development and environment were not explicated, how they make the topic difficult to teach. Other instruments did not reveal what makes the topic difficult to teach. In classroom observation, two teachers have shown their understanding that graphical representation of motion is difficult to teach unless the students are introduced to the graph. Therefore, the teachers have no good understanding of what makes the topics difficult to teach.

Conceptual Teaching Strategies

These are mainly the best teaching approaches in a given context or for a given topic (Mphathiwa, 2016). In this study, a student-centered approach which is based on constructivist learning theory is considered the best strategy to help students construct their knowledge of Newton's law of motion and Graphical representation of motion.

From the data collected using two instruments (lesson plan and questionnaire), the teachers intended to use two methods (lecture and demonstration), which indicates that the teachers intended to make their class more teacher-centered. The teachers did not provide the procedures they intended to follow for the teaching strategies they have chosen. For example, in computing average velocity from a velocity-time graph, they intended to compute total displacement and total time taken, and then divide total displacement by total time. However, they did not explicitly the main idea of how to compute the total distance from the velocity-time graph.

In addition to the lecture and demonstration, the teachers intended to use more methods as they provided in their CoRe. They intended to use question-and-answering and group discussion. Also, some teachers justified the teaching procedures they intended to follow. As revealed in their CoRe, the teachers intended to make their class partially student-centered and partially teacher-centered.

In the teachers' class, the number of teaching strategies used was greater than they provided in other instruments. They have been using question-and-answering, group discussion, note giving, problem-solving, lecture, and demonstration. Every teacher has been using question-and-answering, note giving, problem-solving, and lecture methods.

Most of the time, every teacher used question-and-answering at the beginning of the class to review the previous lesson. Questions raised were low level and focused on one learning domain: cognitive domain. The Group discussion method was only used by two teachers only. A teacher's demonstration has failed in the class, and the teacher could not investigate why the demonstration failed, which indicates that the teacher was not planned well and tested the demonstration before the class.

Even though the lecture method was used frequently by each teacher because of their poor English language and some teachers' limited content knowledge, it was poor. In general, the methods chosen by both trained and untrained groups were appropriate to teach the topics. However, most teachers lack planning; as a result, their strategies were not explicated.

Representations including analogies

It involves selecting and using varied illustrations like diagrams, pictures, simulations, tables, and oral/written presentations to navigate the topic. It is part of the ability to understand student background experiences and misconceptions and relate them to the learning of the topic (Mphathiwa, 2016).

Representations the teachers have been using in their class were: verbal, demo, symbolic, mathematical, tabular, graphical, and diagram to teach Newton's laws of motion and/or graphical representation of motions. Verbal representation has been used most frequently among all teachers. Teachers' choice of representations to teach both Newtons' laws of motion and graphical representation of motion was appropriate and relevant. However, some teachers lack the use of multiple representations. They use only one or two representations. Also, there are representations that both groups did not use in their class, such as chart paper, which can be made by local materials in the school pedagogical center. The use of different visual representations depends on the schools' resources and the teachers' devotion, knowledge, and skill. It was observed that all teachers except two teachers from the trained group had not shown readiness to use visual materials that were easy to access from schools pedagogic center or prepare from locally made materials in teachers' classes.

Most teachers' use of chosen representations was poor. In mathematical representation, a teacher from a trained group interpreted the equation $F_A = -F_R$ as action force is equal to the negative of reaction force, and the reaction force is equal to the positive of the action force. These contradict Newton's third law: action and reaction forces are equal in magnitude and opposite in direction. Even though a teacher from the untrained group used force diagrams to teach action and reaction forces, she could not explain the diagram very well. She sketches the diagram but did not show the forces and their relation explicitly.

Two teachers from the trained group have been using verbal representation in explaining concepts better than other teachers. They explain ideas in a short and precise manner, and their English language was better. Other teachers were very poor in their verbal representation in explaining ideas. What made their verbal representation poor were their English language and limited content knowledge on the topics they were teaching. Relatively, all teachers' textual representations were better than their explanations.

A grade 8 teacher from the untrained group did not use tabular representation in plotting graphs, which made the work of the teacher complex and non-comprehensible. Graphs of two teachers from the untrained group were not clear. In their graph, the scales were not visible, the lines were not drawn straight, steps they followed in drawing graphs were not clear, and two or more graphs were drawn on the same plane. These made teaching non-comprehensible. These may have happened because the teachers lack the skill of drawing graphs. Grade 8 teachers have been using equations of motion in interpreting motion graphs rather than using the properties of graphs as per the curricula' objective.

Only one teacher from the untrained group has tried to use an analogy. His analogy was misleading. He used students' uniforms (students wearing the same cloth) as an analogy for uniform motion. In uniform motion, the motion is about an object that moves with the same velocity, but students' uniform clothes are about students' clothes that are the same color, which tells us failure in the current Ethiopian education system.

In three instruments (lesson plan, CoRe, and questionnaire), the teacher provided more of a verbal representation, and they did not describe very well how they are going to use it. Therefore, to explore teachers' representation and analogy, it is better to use classroom observation than others. This study revealed that teachers' intended representations were limited, whereas, in their class, teachers used more representations, which indicates that what teachers planned on papers were different from what they did in their classes'.

Chapter 5: Finding, Conclusions, and Recommendations

5.1 Introduction

This chapter concludes the study based on discussions from section 4.7. Firstly, I revisit the research questions and respond to them in light of the study's main findings. The chapter then takes into account the implications of the findings for teaching in general and the teaching of topics on Newton's laws of motion and graphical representation of motion in Addis Ababa, SCPS.

Questions that guided my research were, "How are the Addis Ababa SCPS teachers' knowledge domains? Moreover, how do the teachers manifest DT in their class?" I have broken the questions into five sub-questions:

1. How did DT manifest in the SCPS physics classroom?
2. How was the SCPS physics teachers' CK associated with grade 7 and 8 physics topics?
3. How was the SCPS physics teachers' PK in teaching 'grade 7 and 8 physics topics'?
4. How was the SCPS physics teachers represent (portray) and manifest their topic-specific PCK related to the teaching of 'grade 7 and 8 physics topics'?
5. How did training on DT and teachers' KDs' affect SCPS physics teachers' implementation of DT?

5.2 Summary of results and how they answered the research questions

The main questions that the study intended to explore were how the Second cycle primers school physics teachers manifest Dialogic teaching in their class and how are their Knowledge domains on Newtons' law of motion and graphical representation of motion. First, I set out to understand the construct of teachers' knowledge domains and Dialogic teaching and their dynamics across the literature so that I could establish the parameters for the theoretical framework of the kind of PCK within which my study lies.

These were described in chapter 2. To help answer the main question, I subdivided it into five sub-questions for the study's components to be explored. Below is a summary of the results.

5.2.1 Research question 1

> How did DT manifest in the SCPS physics classroom?

The result indicated that every teacher could not demonstrate all features of DT. Therefore, according to Alexander (2008) in every class, there was no dialogic teaching. There were variations among teachers in every feature of DT.

From five teachers' implementation of DT, **purposeful** feature was better demonstrated. Every teacher except a few addressed the topic's contents and planned and structured it with specified learning goals in view (Alexander, 2008). Few teachers have been addressing contents out of the topics and beyond the level of the students.

Most teachers partially demonstrated the collective feature of DT. In these teachers' classes, sometimes students participate in the lesson, and the teachers also use recitation and/or instructional teaching talk repertoires (Alexander, 2008). In a few teachers' classes, the repertoires of teaching talk were recitation and/or instructional. The teacher-centered approach was dominant in their classes.

The most difficult features of DT for the teachers to implement in their class were **reciprocal** and **cumulative** features. In every class, there were no contesting ideas on which students agreed or refute. Moreover, students were not encouraged to reflect on their ideas, and once the teachers had got the correct answer or idea from the students, they did not look for other student's ideas.

The cumulative features of DT were partially demonstrated in some teachers' classes, and in other classes, almost there were no supportive and cumulative features. The other important points that the result indicated were that training on DT helps teachers better demonstrate DT in their class, and teachers who have achieved better in their knowledge domains have better-demonstrated DT.

5.2.2 Research question 2

> How was the SCPS physics teachers' CK associated with grade 7 and 8 physics topics?

The result revealed that: most teachers' conceptual and procedural knowledge was less than average, and every teacher has misconceptions in Newtons' laws of motion and graphical representation of motion. The extent of misconception varies from teacher to teacher. Some teachers were not recommendable to teach at this level.

Areas of teachers' misconceptions were inertia, the relationship between velocity and acceleration, computing average velocity, and average acceleration from a graph. Every teacher has misconceptions in computing average velocity and average acceleration from a graph. The misconceptions were similar to students' misconceptions identified in the study done by (Thornton & Sokoloff, 1998; Clement, 1982; Brown & Clement, 1989; Thijs, 1992), and consistent with Aristotelian mechanics.

5.2.3 Research question 3

> How was the SCPS physics teachers' PK in teaching 'grade 7 and 8 physics topics'?

The result has revealed that the SCPS physics teachers' pedagogical knowledge was mixed. The teachers have a good understanding of classroom management regarding classroom rules, motivation, and intervening against misbehaving students. However, these understandings did not demonstrate in most teachers' classes. There were no rules posted in teachers' classes, and students stood up just when the teachers entered the classes. Most teachers have an authoritative view. They argue that teachers should know everything they teach and transmit knowledge to the students.

The teachers believe that using different teaching methods helps students understand better; students learn from their misconceptions and peers; student-centered class promotes students' understanding. On the contrary:

- Only a few teachers have been using different teaching methods.

- Every teacher looks for the correct answer or provides the correct answer instead of searching for other ideas to remove students' misconceptions.
- The lecture method (teacher-centered) was used in most teachers' classes.

The teachers believe that a teacher should know his students, and they argue that knowledge of students helps the teacher to decide and choose the appropriate teaching methods. On the contrary, most teachers have no skill in assessing their students. Some teachers have listed the three phases of the assessment, but no one mentioned their purpose.

5.2.4 Research question 4

> How was the SCPS physics teachers represent (portray) and manifest their topic-specific PCK related to the teaching of 'grade 7 and 8 physics topics'?

Students' prior knowledge and misconceptions: The result shows that the teachers identified different students' misconceptions. The misconceptions are: velocity-time graph for both uniform and uniformly accelerated motion are the same; objects around the Earth surface do not exert forces on the Earth; if the velocity of a body changes its acceleration also changes; force and acceleration have no relation.

Curricular Salience: The result shows that in their CoRes most teachers could provide contents that are consistent with the objective of the topics. Their lesson plan misses some content. Some teachers could not provide a logical sequence of concepts and provided concepts beyond the students' level.

What makes the topic difficult to teach: The result indicates that in their CoRes, teachers have identified resources, complex concepts, contextual problems, Newton's laws of motion, and graphical representation of motion that are difficult to teach. In their classes, a few teachers have demonstrated that how graphical representation is difficult to teach unless students are introduced to graphs. Difficulties identified are both logical and conceptual.

Conceptual Teaching Strategies: The result shows that strategies, teachers intended to use and strategies they used in their class were different, generic, and similar to

Mphathiwa (2016)'s. The lesson plan and questionnaire intended to use lecture and demonstration methods, but they did not explain their strategies. In CoRe, they intended to use other methods in addition to lecture and demonstration methods. The strategies are appropriate, but every teacher did not provide rationales for their chosen strategies. Strategies the teachers had been using in their class more frequently was the lecture method.

Representations including analogies: The finding has indicated that most teachers have been using multiple representations in their class, whereas what they intended to use was limited. The most frequently used representation was verbal, and it was very poor because of the teachers' English language. In the use of different representations, the teachers lack knowledge, skill, and planning. Only a teacher tried to use an analogy, and it was irrelevant to the concept.

5.2.5 Research question 5

> How did training on DT and teachers' KDs' affect SCPS physics teachers' implementation of DT?

The result indicates that in implementing DT in the SCPS physics teachers' class, teachers who had higher knowledge domains in Newtons' law of motion and graphical representation of motion had better-demonstrated features of DT in their class than teachers who had lower knowledge domains. From five features of DT, those teachers with higher knowledge domains and lower knowledge domains have similarities in demonstrating reciprocal and collective features of DT. In the other three features of DT, teachers with higher knowledge domains have demonstrated better than lower knowledge domains. Therefore, teachers' knowledge domains positively affect the implementation of DT in their class.

Also, the result indicated that in implementing DT in the SCPS teachers' class, the teachers who had training on DT better-demonstrated features of DT in their class than teachers who had no training on DT. From five features of DT, the two groups have similarities in reciprocal features of DT. In the other four features of DT, the two groups were different. Teachers who had training on DT have demonstrated better than teachers who have no training. Therefore, training on DT affects the implementation of DT positively.

5.3 Conclusion and Recommendations

5.3.1 Conclusion

This study focused on exploring teachers' knowledge domains and implementing dialogic teaching on Newtons' law of motion and graphical representation of motion in Addis Ababa, Ethiopia. The study focuses on topic-specific knowledge and promotion of democratic culture, emphasizing the cognitive, creative, productive, and appreciative potential of citizens through a student-centered approach Transitional Government of Ethiopia (1994).

The participating teachers did not exercise the DT. Similar to what Alexander argues, most teachers have been limiting themselves to familiar teaching talks such as recitation, instruction, and exposition. Those few teachers who tried to make their class dialogic also lack some features of dialogic teaching. Moreover, the other features were limited in their implementation. The most difficult features the teachers could not demonstrate in their classes were the reciprocal and supportive features, and the feature that was demonstrated better was the purposeful feature. Teachers who have had training on DT have demonstrated better than teachers who have had no training.

Similarly, teachers who have higher knowledge domains have demonstrated better than lower knowledge domains. The result indicates that training on DT affects the implementation of DT positively, and teachers' knowledge domains have a direct impact on the implementation of DT. In addition to teachers' poor CK, their weakness in communicative English, which is a medium of instruction, made teachers' class non-dialogic.

Most teachers were knowledgeable about Newton's laws of motion and graphical representation of motion, but every teacher had misconceptions in some concepts. The extents of their misconception vary from teacher to teacher. As a result, some teachers were leading students to misconceptions. Moreover, some teachers teach without having adequate content knowledge of what they were teaching. The finding indicated that in conceptualizing physics (grades 7 and 8), especially on Newton's laws of motion and graphical representation of physics, teachers need in-depth professional development training.

Regarding teachers' pedagogical knowledge, the teachers were informed and familiar with pedagogical terms. They have listed appropriate teaching methods, techniques of gathering information for assessment, and how to manage their classroom. In contrast, most teachers lack planning their chosen teaching methods, classroom management, and classroom assessment. These made their pedagogical knowledge superficial.

The finding also identified that most teachers could not transform their content knowledge into easily comprehensible knowledge. The teachers have been identified some students' misconceptions, but could not challenge their students' misconceptions in their class. They identified different teaching strategies, but most did not provide clear steps they intended to follow, and what they demonstrated in their class lacked coherency. Difficulties identified to teach the topics were generic, which were contextual and lacked explanations. Few teachers identified difficulties due to complex concepts in the topic. Even though the teachers identified, chose, and tried to use numerous representations, they did not give the rationale for their choice, and because of their limited knowledge and skill, they did not use effectively. The teachers could not identify and use analogies in their class. In general, because of their limited KDs. Some teachers were not recommended to teach at these grade levels.

5.3.2 Recommendation

My recommendations are:

1. The problem of the medium of instruction was severe. Either the medium of instruction should be the mother tongue or teachers should have at least good knowledge of communicative English.
2. Most teachers need professional development training, and during their training,

prospective teachers should have been well-mentored, supervised, and supported for a long time for teaching practice.

3. In this study, each instrument was administered to nine SCPS teachers, and the study was qualitative. The number of participants should be increased to generalize, and the quantitative method should also be applied.
4. The study focuses on Newtons' law of motion and graphical representation of motion. However, there are other physics topics left out in this study. I suggest that other physics topics, such as electricity and magnetism, waves, heat, etc., should be explored in teachers' knowledge domains.
5. Caution must be taken in choosing participants from in-service teachers, as they seem to be reluctant to respond urgently and participate in research.

5.4 Implications

This section discusses the implications of the study for SCPS physics policy implementation; Teacher Education and professional development; and The Department of Curriculum Development and Evaluation.

5.4.1 Second Cycle Primary School physics policy implementation

The education policy Transitional Government of Ethiopia (1994), and curriculum framework for Education Ministry of Education (MoE) (2009a) recommend that education: should promote democratic cultures; implementing sound pedagogical principles in which students encouraged to take part in their education; teacher trainees have appropriate abilities for teaching profession; and primary education in nationality language and the physics syllabus for Grades 7 and 8 Ministry of Education (MoE) (2009b) recommend students at this level should be given exercises, which are nearly qualitative rather than quantitative, asked to draw pictures, interpret graphs, write short explanations or provide other answers that do not involve significant calculations.

In contrast to these recommendations, the result of the study shows that: due to absence of DT in most teachers class and limited teachers' knowledge domains (CK, PK, and PCK) of most teachers, the autocratic and teacher-centered class were observed;

and some teachers lead their students to misconception; could not make lesson comprehendible to the students; focus on quantitative than qualitative features of the topics and teach students beyond students level. These indicate that there is a gap between the intention of the policy and the actual happening in the school.

5.4.2 Teacher Education and professional development

Teacher education and training affect the development of teachers' knowledge domain, and it is one of the potential sources of teacher subject-matter knowledge (Kleickmann et al., 2013). The finding indicates that most teachers from nine participants appeared to be limited in Newton's law of motion and graphical representation of motion, and even though their goals are indicated in the grades 7 and 8 physics syllabuses, some teachers disregard the goals.

These indicate that in teacher education and professional development programs, SCPS physics contents should be incorporated, and the pedagogy courses should focus on transforming this content knowledge into teachable knowledge. Therefore, it is the responsibility of teacher training institutions (universities and colleges) and teacher training and development department to develop concrete teacher education and development activities to enhance teachers' KDs concerning physics contents they are intended to teach.

5.4.3 The Department of Curriculum Development and Evaluation

The curriculum development activities involve the syllabus's determination, preparation of instructional materials, and the implication of the curriculum (Melese et al., 2019). This study identified that one of the possible reasons for confusion/misconception of the SCPS physics teacher in computing average velocity and average acceleration from a table and a graph were textbooks. The textbooks did not demonstrate how to compute velocity and acceleration from tabular data and interpreter velocity and displacement time graphs, and the textbooks started with a graph rather than starting from tabular data and changing that tabular data into a graph. These indicate that the Ethiopian curriculum development department (General Education Department) needs to update the education materials so that it is informative and sequential.

Moreover, even though the education and training policy (Transitional Government of Ethiopia, 1994) recommends democratic citizen and student-centered teaching approach, a curriculum framework for Ethiopian education (Ministry of Education (MoE), 2009a) did not give Ephesian to oracy, instead, it focuses on literacy and numeracy. This research indicated that the DT approach should be incorporated as a way of implementing the intended curriculum.

5.5 Limitations of the Study

Data have been collected from nine teachers only. This size limits the generalizability of the result. Questionnaire items developed to test the SCPS physics teachers' knowledge domains by the researcher might not represent the population so that it can mislead the result of the research.

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Appendix A: CoRe

A.1 Grade 7 Physics CoRe template

The big ideas in grade 7 Newton's Law of Motion:

Big Idea A: Inertia

Big Idea B: Acceleration is proportional to net force applied

Big Idea C: For every force there is equal and opposite reaction force

Table A.1: CoRe template for grade 7 physics

CoRe for grade 8	Important Ideas/Concept		
	Big Idea A	Big Idea B	Big Idea C
1. What you intend the students to learn about this idea?			
2. Why it is important for students to know this?			
3. What else you know about this idea (that you do not intend students to know yet)?			
4. Difficulties/limitations connected with teaching this idea			
5. Knowledge about students' thinking which influences your teaching of this idea			
6. Other factors that influence your teaching of this idea.			
7. Teaching procedures (and particular reasons for using these to engage with this idea)			
8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).			

A.2 Grade 8 Physics CoRe template

The big ideas in grade 8 graphical representation of Motion:

Big Idea A: Graphical representation of uniform motion

Big Idea B: Graphical representation of uniformly accelerated motion

Table A.2: CoRe template for grade 8 physics

CoRe for grade 8	Important Ideas/Concept	
	Big Idea A	Big Idea B
1. What you intend the students to learn about this idea?		
2. Why it is important for students to know this?		
3. What else you know about this idea (that you do not intend students to know yet)?		
4. Difficulties/limitations connected with teaching this idea		
5. Knowledge about students' thinking which influences your teaching of this idea		
6. Other factors that influence your teaching of this idea.		
7. Teaching procedures (and particular reasons for using these to engage with this idea)		
8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).		

A.3 Guidelines for quantifying PCK

Table A.3: Guidelines for quantifying PCK (Mavhunga & Rollnick, 2011)

PCK Components	(1) Limited	(2) Basic	(3) Developing	(4) Exemplary
Curricular Saliency	● Identified subordinate ideas and pre-concepts are a mix with those of other topics or no subordinates provided ● Sequencing no value due to mixed concepts ● Reasons given for importance of topic limited to general benefit of education ● Inaccurate content or misunderstands big idea ● Possible sources of confusion not identified	● Not all Big ideas have subordinate concepts identified however those identified are correct ● Sequencing can be followed however has one illogical placing of key concepts (Big Ideas) and also for the suggested pre- concepts. ● Reasons given for importance of topic exclude conceptual considerations such as scaffolding/sequential development of understanding for other topics in the subject. ● Knowledge often limited to what student s need to know ● Possible sources of confusion not identified	● Identifies correct subordinate ideas and shows links to Big ideas with no additional explanations ● Provides logical sequence of concepts of some of the Big Ideas within reason ● Identified pre-concepts includes those used in the definition of current topic ● Reasons given for importance of topic include reference to conceptual scaffolding/sequential development of understanding of other topics in the subject without specifying the topics ● Research evident, demonstrates sound understanding of topics beyond what students need to know ● Identifies possible sources of conceptual confusion at a surface level	● Identifies correct subordinate ideas and explains links to Big Ideas ● Provides logical sequence of concepts of all the Big Ideas and pre-concepts logical within reason ● Identified pre-concepts include those needed in discussing the introductory definitions and those sequentially needed in the next Big Ideas of the current topic. ● Reasons given for importance of topic include conceptual scaffolding/sequential development of understanding for specified subsequent topics in the subject. ● Comprehensive, well organised knowledge of topics; foregrounds main ideas; networked examples ● Identifies possible sources of conceptual confusion
Student Prior Knowledge including misconceptions	● Not perceptive of students needs ● No identification, acknowledgement ● No consideration of student prior knowledge or misconceptions	● Identifies misconception or prior knowledge on one big idea only ● Aware of student s needs but not able to find appropriate balance	● Identifies misconception or prior knowledge on two or more big ideas ● Provides the basis and reasons for the consistent students' knowledge ● Aware of student s needs; considers their context and diversity	● Identifies misconception or prior knowledge on all big ideas ● Provides the basis and reasons for the consistent students' knowledge ● Identifies and considers diversity in students' ability, learning style, interest, developmental level and need. ● Confronts misconceptions/confirms accurate understanding Subtle understanding of student strengths and weaknesses
Representation Explicitly in CoRes	● Limited to use of analogies, demos, etc.) representation with no explanation of specific links to the concepts represented	● Describes or demonstrates ways to model or illustrate a concept (analogies, demos, diagrams etc.) and use of representation without explanatory notes to make the links to the aspects of the concept being explained (For only one big idea)	● Describes or demonstrates ways to model or illustrate a concept (analogies, demos, diagrams etc.) and use of representation with explanatory notes linking the two representation to the aspect(s) of the concept being explained (For more than one big idea)	● Describes or demonstrates ways to model or illustrate a concept (analogies, demos, diagrams etc.) or symbolic representation and ● Use of detailed representation to enforce a specific aspect (s) of the concept being explained
What makes topic difficult to teach	● Leaves blank space; reasons not given ● Identifies broad topics without specifying the actual sub-concepts that are problematic	● Identifies only the contextual constraints ● Identifies broad topics without specifying the actual sub-concepts that are problematic	● Identifies specific concepts with reasons related to specified prior knowledge of students or common misconceptions for at least one big idea	● Identifies specific concepts with reasons related to prior knowledge of specified students or common misconceptions for more than one big idea

PCK Components	(1) Limited	(2) Basic	(3) Developing	(4) Exemplary
Teaching Strategies (in, about, for)	● Provides no evidence of acknowledgement of student prior knowledge and misconceptions ● Lacks aspects of curriculum saliency (e.g. corresponding subordinate concepts in a topic, sequencing for scaffolding learning, awareness of the background concepts needed before teaching the topic) ● There are few opportunities for student development; Suggested activities are largely teacher centred ● Justification for choice of teaching strategy not provided	● Acknowledges student misconceptions with no corresponding confrontation strategy ● Lacks aspects of curriculum saliency ● Uses a few T/L strategies with little variation hence limited involvement of student s as student s are given tasks that develop recall ● No justification for choice of teaching strategy	● Overall, strategy workable ● Considers confirmation/confrontation of student prior knowledge and/or misconceptions ● Considers at least one aspect related to curriculum saliency: sequencing or what not to discuss yet or emphasis of important concepts ● Provides justification for choice of teaching strategy but not necessarily aligned to EE ● There is evidence of encouraged student involvement; experiments with a variety of T/L strategies hence student s given comprehension or application tasks	● Overall , excellent strategy to teach required concept ● Considers confirmation/confrontation of student prior knowledge and/or common misconceptions ● Considers at least two aspects related to curriculum saliency: sequencing, what not to discuss yet, emphasis of important conceptual aspects, etc. ● Provides justification for choice of teaching strategy consistent with EE specific strategies (in, about, for the environment) ● Highly student centred lesson; thoughtfully selects and effectively uses a variety of T/L strategies appropriate to the content and students.

Appendix B: Lesson Plan

B.1 Lesson plan Template

Name of the school: ____________________ Date: ____________

Teacher's Name: ____________________ Duration of the period: ____________

Grade: ____________________ Section: ______________

Subject: ____________________ Reference: ____________

Unit of Lesson: ____________________ Sub-unit of the Lesson: ______________

Topic of the day: ____________________

Rational of the topic:

____

____

Pre-requisite Knowledge:

____

____

Learning Objectives: At the end of this lesson, students will be able to:

____

____

Stage	Time	Learning Content	Teacher's Activities	Student's Activities	Learning Assessment (F.C.A)
Introduction					
Lesson Development					
Conclusion					
Assessment (After instruction)					

Teaching and Learning Materials:

Learner Support (for slow-learners, fast learners, students with disability, etc.)

Comment and Signature of the department head:

Appendix C: Questionnaire

Name	....	....	Age ....
Qualification	1^{st}	2^{nd}	3^{rd}.............
Service	1^{st} cycle	2^{nd} cycle	
Gender	Female ☐	Male ☐	

Please write your answer in the space provided. If the given space is not enough use extra separate page or back of the page.

CK and PCK Questionnaire

1. An object stops its motion because of lack of action force to keep the object going.
   (a) What do you say about this idea? Is it correct or incorrect? How?
   (b) How do you make the idea clear to your students? (strategies and representations used)
   (c) If there is misconception, what are the root causes of the misconceptions?
2. Velocity-time graph for both uniform motion and uniformly accelerate motion is horizontal line.
   (a) What do you say about this idea? Is it correct or incorrect? Explain?
   (b) How do you make the idea clear to your students? (strategies and representations used)
   (c) If there are misconceptions, what are the root causes of the misconceptions?
3. Magnitude of gravitational force of the Earth on an object around Earth is equals to the magnitude of gravitational force of the object on the Earth. On the other hand an object around the earth accelerates toward the earth while the earth does not.
   (a) What do you say about this phenomenon?
   (b) How do you explain this idea to your students? (strategies and representations used)

(c) If there are misconceptions, what are the root causes of the misconceptions?

4. If velocity of an object changes, its acceleration also changes.
   (a) What do you say about this idea? Is it correct or incorrect? Explain?
   (b) How do you make the idea clear to your students? (strategies and representations used)
   (c) If there are misconceptions, what are the root causes of the misconceptions?
5. Action and reaction forces are equal and opposite in direction and the two forces act on the same object.
   (a) What do you say about this ideas? Are they correct or incorrect? How?
   (b) How do you make the ideas clear to your students? (strategies and representations used)
   (c) If there are misconceptions, what are the root causes of the misconceptions?
6. Students may say that weight of an object on the earth and on the moon are different.
   (a) What do you say about this ideas? Are they correct or incorrect? How?
   (b) How do you make the ideas clear to your students? (strategies and representations used)
   (c) If there are misconceptions, what are the root causes of the misconceptions?

7. Distance of an object, moving with uniform motion, as a function of time is given in Table C.1. Students' answers to a question: What is the speed of the object at time $t = 0$? where different. Some of students answer were 0, $10\ m/s$, $20\ m/s$, $30\ m/s\ and\ un$

Table C.1: Uniform Motion

S(m)	0	10	20	30	40
t(s)	0	1	2	3	4

   (a) Which one is the correct answer? How? explain.

(b) How do you make the ideas clear to your students? (strategies and representations used)

(c) If there are misconceptions, what are the root causes of the misconceptions?

8. Figure C.1 is a velocity time graph of a body moving along a straight line. Students' answer to a question: In time interval from 0 to 10 s, what is the average velocity of the object? were different. Some of the students' answers were $0m/s$, $4m/s$, $6m/s$, $5.4m/s$, $3.2m/s$, and $4.2m/s$.

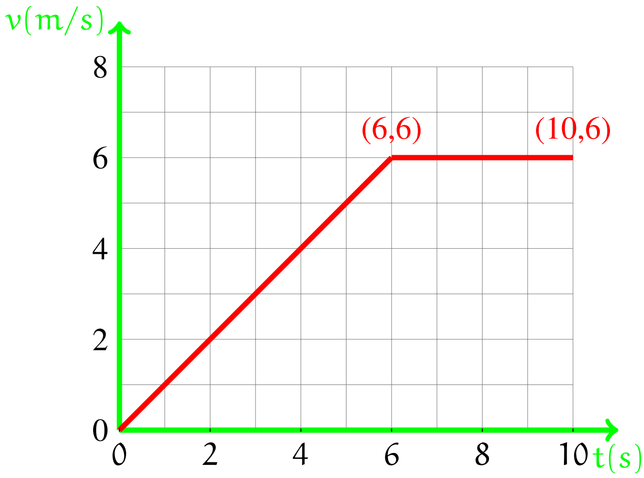

Figure C.1: v-t graph

(a) Which one is the correct answer? How? explain.

(b) How do you make the ideas clear to your students? (strategies and representations used)

(c) If there are misconceptions, what are the root causes of the misconceptions?

9. A teacher ask his students, What is the acceleration of the motion shown in v-t graph (Figure C.2)? Some of the students' answer were $0m/s^2$, $0.8m/s^2$, $8m/s^2$, $1.25m/s^2$, and $2.25m/s^2$.

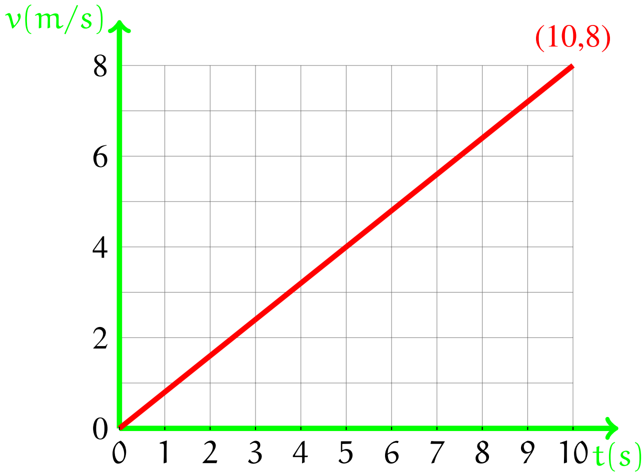

Figure C.2: v-t graph for Uniformly accelerated Motion

(a) Which one is the correct answer? How? explain.

(b) How do you make the ideas clear to your students? (strategies and representations used)

(c) If there are misconceptions, what are the root causes of the misconceptions?

10. Students argue velocity and acceleration of an object are always in the same direction of net force applied on the object.

    (a) What do you say about this idea? Are they correct or incorrect? How?

    (b) How do you make the ideas clear to your students? (strategies and representations used)

    (c) If there are misconceptions, what are the root causes of the misconceptions?

PK Questionnaire

11. A teacher should know his/here students. Do you agree or not? If yes about what and how do he/she know and what is the importance of knowing his/here students? If not why?

12. What is the importance of motivating your student? How do you motivate them, for example when you teach about Newton's Laws of motion?

13. Teacher Kebede argue that ”A teacher should not wast time in allowing students wrong answer if he get the correct answer”. Do you agree with Teacher Kebede

or not? why? What is the purpose of looking for extra wrong answer?

14. Teacher Kebed is a hard working physics teacher, he bring full information to his students, about his lesson. Students don't need to search for any information. What do you do you say about teacher Kebede?
15. A student may talk to his peer while you are introducing. How do you stop this talk without distracting other students? What is the purpose?
16. In your class you want students working together to construct knowledge, what kind of desk arrangement do you think the most appropriate? why?
17. At the beginning of an academic year, teachers develop set of classroom rules. What are the importance of classroom rules ? In order to make the students respect the rules and feel ownership of the rules what should a teacher does?
18. How do a teacher maintain positive teacher-student relationship? what is the purpose of positive teacher-student relation for classroom management?
19. A teacher respond to minor misbehavior beginning with a nonverbal interaction and moving to a verbal intervention. Why he choose first a nonverbal intervention?
20. Using different teaching methods are recommended. Why? explain.
21. A teacher may ask students to plot velocity time graph by giving a data. What learning domain the teacher wants to assess?
22. What is classroom assessment for you? For what purpose do we use assessment? When does a teacher assess his student? Explain the purpose of each assessment.

Appendix D: Interview

D.1 Interview protocol

1. What is the purpose of teaching aid?
2. Which language (English or Amharic) do you recommend for grade 7 and 8 students to make the students learning comprehendible.
3. How do you know your students understand what you taught?
4. In your class, your student may ask difficult question that you couldn't answer. What do you say to this student? Do you accept you don't know?
5. Which one is better approach? Admitting students questions at any time or Admitting only at the end of your presentation?

Declaration

I, the undersigned candidate declare that this dissertation entitled: *Dialogic Teaching Approach in teaching Physics vis-à-vis Physics Teachers' Knowledge Domains in Addis Ababa* is an original research I conducted under the supervision of *Professor Vanessa Kind and Professor Mulugeta Atinafu.* The full or any part of this dissertation has not been submitted for any degree or examination in this or any other university and therefore, it is not by any means a replication of a work already done by no one. Further, I declare that all the sources I have used or quoted have been indicated and acknowledged as complete references in this dissertation.

Candidates name: Deresse Terfa

Id number: GSR/3472/07

Signature ____________________ Date: May 25, 2020

We, Deresse Terfa's dissertation supervisors testify that this dissertation has been developed under our supervision and we approved it to be submitted to the department for evaluation as a fulfilment of the requirements for the degree of Doctor of Philosophy.

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