Enhancing pre-service teachers' diagnostic competence in Physics misconceptions at public universities in Tanzania

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Executive Summary

Teachers require to diagnose students' learning needs in order to plan and carryout effective lessons, a process similar to medical doctors diagnosing their patients before treatment. While it is crucial to enhance diagnostic competence in teachers, an issue remains about how we can best improve this competence among undergraduate pre-service teachers. In the teaching and learning process of science in middle or high schools, misconceptions can hinder learning of new Physics ideas if teachers do not detect and correct them in time. The current research carried out a meta-analysis of 22 empirical studies aimed at fostering diagnostic competences through intervention in teacher and medical education, summarized the findings, revealed the overall effect size, and examined the moderating factors. Following the results of the meta-analysis, we designed an experimental study to investigate the effects of problem solving and example-based learning instructional approaches on enhancing pre-service teachers' diagnostic competence in Physics misconceptions.

The meta-analysis revealed a positive medium mean effect size (g = 0.37) of interventions on fostering the development of diagnostic competences among undergraduate students in both domains. The moderator analysis suggests that an instructional approach is a significant moderator when we apply problem solving during the learning phase of an intervention. The experimental study revealed that both problem solving and example-based learning significantly enhanced pre-service teachers' diagnostic competence in form of conceptual knowledge, but not the procedural knowledge. Problem solving instructional approach was more effective than example-based learning on enhancing diagnostic competence. The pre-service teachers' diagnostic competence in the form of conceptual and procedural knowledge positively correlated with germane cognitive load, while it negatively correlated with intrinsic and extraneous cognitive loads. Example-based learning instructional approach significantly influenced both intrinsic and extraneous cognitive loads when compared with problem solving. Cognitive load did not significantly mediate the effect of the instructional approaches on diagnostic competences, and a rating scale questionnaire differentiated between the three types of cognitive load, but did not clearly discriminate between intrinsic and extraneous cognitive loads.

The meta-analysis findings imply that learning to diagnose various aspects through problem solving is an effective means of advancing undergraduate students' diagnostic

competences. Learners' prior diagnostic knowledge seems to be a covariate on enhancing diagnostic competences through interventions. An experimental study findings also imply that the problem solving instructional approach can enhance pre-service teacher's diagnostic competence in identifying pupil's Physics misconceptions better than example-based learning. In practice, the current research supports the assumption that integrating diagnostic practices into the Physics-methods course curriculum during undergraduate training programs can improve pre-service Physics teachers' formative assessment skills. Some limitations can be accounted for by the findings in both studies. With respect to the meta-analysis, the restrictions of robust variance estimation method when estimating meta-regressions especially for moderator analyses could have limited the findings due to imbalances of level of some categorical moderator variables. This could have then affected the degrees of freedom and hence the power for moderation effect. In the experimental study, the random errors that might occur due to extraneous variable (e.g. individual ability) that could have affected the outcome measures rather than interventional treatment, and the assessment of pre-service teachers' diagnostic knowledge through a same knowledge test could have also limited the findings.

In conclusion, the meta-analysis supports the development of diagnostic competence through interventions (with a medium effect size), and indicates that problem solving is the best instructional approach. The meta-analysis also seems to point out the fact that example-based learning instructional approach may better fit learners with lower prior knowledge, whereas, problem solving may better fit learners with higher levels of prior knowledge. With respect to the experimental study, undergraduate pre-service teachers seem to learn abstract concepts and ideas about the diagnosis process better through problem solving than example-based learning. Both instructional approaches seem to facilitate the diagnostic competence effectively, if we consider the germane cognitive load high, while keeping the intrinsic and cognitive load to a minimum. The current research further emphasizes the need for a similar meta-analysis to include more studies and alternative moderators (e.g. types of feedbacks, prompts, and so on), and an experimental study to compare the effects of problem solving and example-based learning on diagnostic competences with immediate and delayed post testing.

Short introduction to the education system in Tanzania

The education system in Tanzania mainland comprises two years of pre-primary education, which is compulsory for all children up to 6 years old (MoEVT 2008). After this early education, they join primary education that lasts for seven years. On the completion of primary education, pupils have to sit for primary school leaving examination (PSLE) which is a requirement for secondary education. Any pupil who wishes to join secondary education has to pass this examination. The pupils who fail or get insufficient grades to join secondary education can either join vocational education (VETA) or integrate with community life. The next educational level is ordinary secondary education, which comprises four years. After completing it, students receive a certificate of secondary education (CSE), which is a requirement for joining advanced secondary education but only possible for those who pass the CSE exams. Advanced secondary education takes two years. Those who do not qualify for advanced level secondary education can also join vocational education or other tertiary colleges. Then, on completing this level, students receive a certificate of advanced secondary education (ACSE) which is also a requirement for joining either university or tertiary colleges. The tertiary education in Tanzania provides ordinary or advanced diploma in various fields or full technical certificate (FTC). The students who successfully complete their ordinary or advanced diploma in various fields or full technical certificate can also join university if they meet university entry qualifications.

The curriculum in pre-primary education consists of basic knowledge acquisition elements according to education and training policy (MoEVT 2008). That is, reading, writing and arithmetic. Pupils at this level learn all subjects in the Swahili language that is not the mother tongue of some children in Tanzania. In primary school, pupils take more subjects in the Swahili language except for the subject English as a foreign language. The subjects include history, geography, civics, personality development and sports, information and communication technology (ICT), science, mathematics, Kiswahili, and English. The students in ordinary secondary school carry out almost the same subjects as in primary school except science, which splits into: Biology, Chemistry and Physics. The medium of instruction at ordinary secondary school education is English except for the Swahili subject, which is a national language. At advanced secondary school, students have to opt for a combination of a few subjects, for instance Physics, Chemistry and Biology (PCB), History, Geography and English language (HGL), and so on. The medium of instruction at this level is also English. Then, university students have to carry out various courses according to a particular degree program and with respect to their backgrounds at ordinary or advanced secondary schools. The universities offer courses according to faculties and departments at various universities in Tanzania. For example, at University of Dar Es Salaam, which is a public university, the faculty of education offers educational courses such as Bachelor of Education with science (BSc.Ed), Bachelor of Education in science (BEd.Sc.), and so on. Students who are taking BSc.Ed have to major in two teaching science subjects (e.g. Physics and Mathematics) and some education or method courses.

The provision of education in Tanzania mainland is done under the ministry of education and prime minister's office-administration and local government (MoEVT 2010). The government is also responsible for funding and grants. The education training policy of 1995 is a driving policy so far and various educational development programs implements it. According to the MoEVT (2010) report, the educational system in Tanzania has undergone major reforms in the last three decades which reflected: the national development vision 2025, national strategy growth and poverty reduction, educational sector development of 2001, and the millennium goals. However, the education system in Tanzania has also faced some challenges for several decades. One of them is the language of instruction especially during the transition from primary to secondary education. At this transition period, the majority of Tanzanian children who do not have a background in the English language struggle considerably because the medium of instruction changes abruptly from Swahili to English. Another challenge is the shortage of learning materials (e.g. textbooks, lab equipments). For a long time this has been a big problem especially for public schools in the rural areas, although the situation appears to improve due to government commitment. Furthermore, the lack of school infrastructures also has been a big challenge for decades. Many primary and secondary schools have faced a serious shortage of classrooms, laboratories, and lab equipments; nonetheless, the government has strived hard to equip all schools with necessary facilities. The shortage of qualified teachers especially for English, Science and Mathematics has been a further issue. In general, the current education system in Tanzania satisfies educational needs of the country in the context of the challenges that the nation has faced so far.

CHAPTER ONE

CONTEXT OF THE RESEARCH PROBLEM

1.0 Introduction

This chapter describes the context of the research problem with respect to the development of diagnostic competence among pre-service Physics teachers. Also, the chapter presents contextual factors behind the need to enhance diagnostic competence in teacher education in comparison to medical education. Finally, the chapter describes the aim of the dissertation as well as an overview of all the chapters.

1.1 Background to the research problem

Diagnostic competence is important for classroom teachers as far as formative assessment practice is concerned. As such, teachers need to develop this competence as early as possible particularly during undergraduate teacher training programs. Teacher training programs require pre-service teachers to develope diagnostic competence similarly to medical education programs whereby fostering the development of diagnostic competence among medical students is crucial (Schmidt et al., 1996). This is because professionals in both fields can obtain information for decision-making through diagnosis processes before teaching their students, or providing correct treatment to their patients, or taking further actions (Heitzmann, 2014; Heitzmann et al., 2015). The comparison between the diagnosis process in teacher education and medical education is further crucial because in both fields human beings are by nature the units of diagnosis. Moereover, in each field the process aims at obtaining information and reducing uncertainty to reach a medical or educational decision and define the course of further actions. For this reason, classroom teachers need to obtain information about students' learning prerequisites in order to improve the learning process, to reflect and respond to students' false conception of ideas, or to regulate their own teaching practices (Barth & Henninger, 2012; Hoth et al., 2016; Schmidt, 1997) similarly to a medical doctor who needs to diagnose a patient's disease before he or she provides a precise treatment (Baker et al., 1999; Eva, 2004; Norman, 2005). For instance, a classroom teacher needs to know about students' conceptual understanding of ideas so that it is easier to make decisions regarding the choice of the instructional approaches according to students' learning styles, selecting appropriate learning materials, or facilitating the conceptual change (Morrison & Lederman, 2003; Thompson & Logue, 2006).

Although it is crucial to enhance teachers' diagnostic competence similarly to medical doctors in hospitals, the issue remains on how we can advance this competence among undergraduate students of teacher education programs (or pre-service teachers) at the university level. That is, how to facilitate diagnostic competence among pre-service teachers similarly to medical students in which advancing diagnostic competence is a basic curriculum requirement. Also, as one of the classroom formative assessment practices, teacher's competence in diagnosing students' learning needs is also essential. The process of diagnosing in teacher education involves a teacher trying to obtain information about student's learning prerequisites before or during the lesson. For instance, classroom teachers need to diagnose learning situations so as to understand how students learn, give appropriate feedback, reflect on their own teaching practices and hence improve teaching and learning process (Barth & Henninger, 2012; Chin, 2001; Heitzmann et al., 2018; Hoth et al., 2016). To do so, they need to advance diagnostic competence that plays a big role in formative assessment practices, for instance, identifying students' thinking or conceptions of ideas.

Apart from the similarities in performing diagnosis in teacher or medical education, classroom teachers and medical practitioners have to clearly diagnose different cases. The definition of diagnostic competence in these two fields is therefore different. For instance, diagnostic competence in teacher education refers to teacher's ability to obtain information about students' learning processes as well as their achievements or thinking (Hoth et al., 2016), or ability to judge students' performance or characteristics in order to improve the learning process (Ohle & McElvany, 2015), or teacher's knowledge of identifying learner's requirements in classroom sessions (Barth & Henninger, 2012). Contrarily, diagnostic competence in medical education refers to the accuracy in clinical reasoning competence or in determining patient's diseases or illness (Chamberland et al., 2015; Neistadt, 1998; Round, 1999), or accuracy in diagnostic performance, depending on physicians' illness scripts or mental structures that are developed either during initial professional or in-service training programs (Schmidt & Rikers, 2007; Mamede et al., 2014). Thus, in order to perform effective diagnosis in medical field, a physician requires an automation of these illness scripts that are stored as schemas which have been defined as the organized bodies of knowledge that are usually stored in the long term memory of a doctor after a successful learning process (Sweller et al., 1998), relating them to the current situation of a patient, and finally to obtain necessary information for making decisions about the treatment.

Another important research issue is how to develop this competence in the course of some instructional strategies during this early professional training similarly to undergraduate medical students in which instructional approaches such as problem solving or example-based learning have been applied. For instance, classroom teachers need to diagnose learning situations so as to understand how students learn, give appropriate feedback, reflect on their own teaching practices and hence improve teaching and learning process (Barth & Henninger, 2012; Heitzmann et al., 2018; Hoth et al., 2016). To do so they need to advance diagnostic knowledge.

In the process of learning science in particular, learners usually come to school with preconceived alternative ideas or naive theories about the physical world around them (Pine et al., 2001; Morrison & Lederman, 2003). Learning usually involves construction of meaning and understanding of ideas through linking new ideas to the existing concepts or knowledge (Chin, 2001; Smith et al., 1994). However, these preconceived ideas have proven to be usually incorrect in the context of well known or accepted scientific ideas and principles, and if not detected and corrected by teachers during the learning process, they can negatively influence learning of new science ideas (Gurel et al., 2015; Smith et al., 1994). Furthermore, science misconceptions can be carried over to higher levels of education if not detected and corrected during the learning process. Science teachers can identify and correct students' held misconceptions during the teaching and the learning process only if they are aware of them. But due to time pressure and accountability for teachers to complete topics or content areas from the syllabus, they may not be able to diagnose students' learning pre-requisites effectively as part of the formative assessment (Chin, 2001; Schmidt, 1997). As a result they assess their students mainly in a summative way, that is to say, they usually measure what students can recall from classroom lessons or from scientific principles and find out what they have learnt from the taught materials rather than from science concepts (Chin, 2001; Smolleck & Hershberger, 2011).

These issues were the motivation behind the current study to investigate how to enhance pre-service teachers' diagnostic competence in Physics misconceptions particularly at undergraduate level. Also, medical education has been closely regarded since learning how to diagnose is a basic curriculum requirement in this field, and that it is possible to adapt their training strategies into teacher education. Finally, the topic of diagnostic competence in identifying pupils' misconceptions in Physics has been a personal topic of interest to the researcher.

1.2 Aim of the dissertation

The aim of this dissertation is to promote an understanding of how to enhance pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics. At elementary, middle or high schools, Physics teachers, similar to other science teachers, are required to develop a set of competences. One of these competences is the diagnostic competence in identifying pupils' misconceptions in Physics. Diagnostic competence is important for Physics teachers in order to understand the learning processes of their learners (Kaltakci-Gurel et al., 2017). However, in order for teachers to diagnose pupils' misconceptions in Physics successfully, they need to be aware of common misconceptions that pupils can hold due to various factors. This is why diagnostic competence as a part of a teacher's formative assessment practices needs to be developed at early stages of teacher training programs, so that prospective teachers can later help their learners to gain correct understanding of science ideas (Smolleck & Hershberger, 2011). Thus enhancing diagnostic competences among pre-service Physics teachers during initial teacher training programs is crucial for the development of their future diagnostic knowledge as well as for their formative assessment skills. Integrating diagnostic practices on how to identify pupils' misconceptions in Physics in the science education curriculum at undergraduate level will enable pre-service teachers to gain diagnostic comepetence that they can later apply to diagnose pupils' misconceptions at schools. Furthermore, the diagnostic competence of identifying pupils' misconceptions in Physics is crucial for teachers to facilitate conceptual change among learners (Morrison & Lederman, 2003; Pine et al., 2001). Finally, pre-service Physics teachers should develop this kind of competence as early as possible in order to understand pupils' thinking and to facilitate a positive learning transfer. That is, learning of new physics ideas from the already learned ideas without interference from pupils' common misconceptions.

1.3 Overview of the dissertation chapters

This dissertation comprised seven individual chapters. The first chapter describes the problem statement and the contextual factors that are behind the need to enhance diagnostic competences in teacher education as compared to medical education. The second chapter describes in details the contrast between diagnostic competence in teacher education and in medicine education, the operational definition of diagnostic competence with respect to the two studies in this dissertation, and an elaboration of Physics misconceptions including their typical examples in the topic areas of Mechanics and Electricity. Chapter two further explains the need for enhancing diagnostic competences in identifying misconceptions. Chapter three describes an overview of instructional strategies and approaches, how learning occurs from the perspective of different instructional approaches, the relationship between learners' prior knowledge and the instructional approaches. In addition, chapter three describes the concept of cognitive load and how cognitive load theory is related to some of the considered instructional approaches. Chapter four summarizes the two main research questions that arise from the literature review presented in the previous two chapters. Chapter five contains a meta-analysis, the first study that was motivated by the contradicting findings from the primary studies that focused on enhancing diagnostic competences in teacher and medical education. The findings from the meta-analysis have guided the researcher to design an empirical study to investigate how to apply some instructional approaches fostering the development of diagnostic competence in teacher education during initial professional training programs. Chapter six contains an empirical study as a follow up study to validate the findings from the meta-analysis. Finally, chapter seven comprises a summary of the studies, general discussions and conclusions for this research project. Also, the chapter describes the recommendation for theory, practice, and future research.

The next chapter presents literature review on diagnostic competences in relation to misconceptions in Physics.

CHAPTER TWO

DIAGNOSTIC COMPETENCE IN PHYSICS MISCONCEPTIONS

2.0 Introduction

This chapter describes in details the concept of diagnostic competence, the contrast between diagnostic competence in teacher and medical education, and operational definitions of the term diagnostic competence as applied in the first and second study. Furthermore, it elaborates on the misconceptions in Physics Mechanics and Electricity.

2.1 Diagnostic competences

The term diagnostic competence has been mostly referred to in various fields in relation to the ability of performing tasks accurately. In medical education, accuracy refers to correctly diagnosing patient's illness or a disease, and identifying the corresponding signs and symptoms (Eva, 2004). However, the term diagnostic competence has also been applied in other fields to refer to the ability to analyze causes or sources of a particular issue, for instance students' learning pre-requisites (for a classroom teacher), or a problem with the engine (for a mechanic). However, in medicine, the term diagnostic competence generally referred to an accuracy in determining patient's illness and the underlying treatment procedures (Baker et al., 1999), or diagnostic reasoning in solving medical problems (Schmidt et al., 1996), or an accuracy in clinical reasoning (Brailovsky et al., 2001; Neistadt 1998), or knowledge of diagnostic process (Eva 2004; Schmidt and Rikers, 2007; Mamede et al., 2014), and the alikes. Recently in teacher education, the term diagnostic competence has been referred to as teachers' ability to determine student's learning pre-requisites (Barth & Henninger, 2012), student's performance, or teacher's own characteristics in teaching (Vogt & Rogalla, 2009). The essence of diagnosing in teacher or medicine education is to obtain information that can be used to make decisions concerning students' learning pre-requisites or patients' treatment.

Diagnosing, either in medicine or teacher education, deals with observable human being characteristics that are of interest according to the aim of the diagnosis. In both fields, the term diagnostic competence can generally be referred to as a set of an individual's dispositions necessary to successfully engage in the goal-oriented gathering and integration of case specific information in order to make some medical or educational decisions (COSIMA research group, in press). Therefore, in both domains, diagnostic competences seem to be important in situations where it is necessary to develop a plan for further actions or in which an immediate action needs to be initiated (Heitzmann, 2014; Heitzmann at al., 2018). As such, diagnostic competence is a basis for the planning, the observations or other forms of case specific data collection while the specific goal in mind is proceeding. A professional diagnosis is thus based on some form of data. In medical education, the primary goal of training is to develop medical students' diagnostic competences in terms of reasoning skills necessary for solving medical problems (Mamede et al., 2014), rich illness scripts for determining patients' diseases (Schmidt & Rikers, 2007), and accuracy in performing diagnoses in clinical medicine (Baker et al., 1999). On the other hand, diagnostic competence in teacher education can also be used as a source of information relevant for teachers to adjust their teaching strategies, for planning and carrying out effective lessons based on the information obtained through diagnosis, and to determine learning opportunities available for students (Barth & Henninger, 2012; Busch et al., 2015; Hoth et al., 2016). As a result, in the past two decades, empirical primary studies which focus on fostering diagnostic competences among medical students or interns, student teachers or teachers in service have increased in number. The process of developing diagnostic competences in these domains has been investigated through interventions and different instructional strategies. The next two sub-sections discuss the concept of diagnostic competence in medical education and teacher education in more details. The contrasts and similarities of the diagnosis process between the two domains are also discussed in the respective sub-sections with reference to some empirical studies conducted in these fields.

2.1.1 Diagnostic competence in medical education

One of the major goals of medical education is to develop diagnostic competences among medical students or experts (Mamede et al., 2012; Schmidt & Rikers, 2007). As such, a key component of diagnostic competences in medical education is clinical competence or clinical reasoning skills. In medical education, clinical reasoning is basically defined as the ability to reason through the set of symptoms and signs presented by a patient in order to generate accurate diagnosis and to recommend an appropriate treatment (Mamede et al., 2014; Norman, 2005; Peixoto et al., 2017). On the other hand, diagnostic competences in medicine is referred to as the acquisition of mental structures that can be used to describe the cause of a disease and its consequences, mental structures that can help a physician to organize and support clinical thinking, or ways in which a physician builds mental representations of diseases consisting of signs and symptoms, its causal mechanism (Mamede et al., 2014; Neistadt, 1998; Schmidt & Rikers, 2007). Moreover, diagnostic competences in medical education is considered as a medical doctor's ability to arrive at a correct diagnose or as a careful analysis of the relationship between signs and symptoms of a disease for a patient (Baker et al., 1999; Eva, 2004; Mamede et al., 2012). The accuracy in diagnosis will depend on the amount of illness scripts which a physician has acquired and stored in memory as mental structures necessary for clinical reasoning in future. Most of the medical education programs insist of developing diagnostics competences among medical students in order to build knowledge and skills necessary for solving medical problems (Schmidt et al., 1996). This process continues in their internship phase of medical training and even later medical experts still need to develop diagnostic competences for the sake of performing their duties more effectively.

Diagnostic competences are important in medical education. One of the advantages of diagnostic competences in the medical field is for medical doctors to be able to detect the core causes of a patient's illness or disease through diagnosing the signs and symptoms (Eva, 2004; Mamede et al., 2014; Norman, 2005). Thus one of the core tasks for clinical teachers is to enable medical students to determine, through a cluster of features presented by a patient, and accurately assign appropriate diagnoses and develop an appropriate treatment strategy. Moreover, diagnostic competences among physicians will enable them to know the root causes of the disease and how to cure them. Then, the information which is obtained through diagnosis can be used to plan a proper treatment because a doctor is aware of the problem which is behind the patient's complaints or symptoms. In this case, without proper diagnosis in the hospital, medical doctors would carry out treatment in trial and error based on the general knowledge they have gained during training about diseases. Thus, acquiring diagnostic competences will enable physicians to build up mental structures or illness scripts necessary for solving medical problems.

In medical education, expertise or clinical reasoning skills necessary for medical students to perform diagnosis can be developed through some phases. Schmidt and Rikers (2007) explained four phases in which medical expertise among medical students can develop during training programs. According to Schmidt and his colleague, expertise among medical students begin to develop as early as during the training phase. At this stage medical students begin to develop mental structures that can be used to explain the causes and consequences of diseases in terms of the underlying biological or pathophysiological processes. According to Schmidt and Rikers (2007), at this stage when students are asked to diagnose a clinical case, they tend to focus on the isolated signs and symptoms while relating the cases with acquired conceptual knowledge. Then in the intermediate stage, medical students attempt to apply the acquired knowledge of concepts acquired during the early stage to describe a patient's signs and symptoms. It is in this stage that the first change in knowledge structures occurs through extensive use and repetition of the acquired knowledge. At the later stage, medical students then begin to practice diagnosis with actual patients, where the second change in knowledge structures occurs. This is a stage where students begin to build up illness structures through expressed-base, contextual or conditional knowledge. Finally, according to Schmidt and his colleague, the interns are then able to store these illness scripts as mental structures, which will also be applied to solve future diagnostic problems.

2.1.2 Diagnostic competence in teacher education

Although the term diagnostic competence has been mainly used in medicine, in the past two decades, it has also been adapted in teacher education. Diagnostic competence in teacher education can then be considered a bite in more details than simple concepts which could simply mean teachers' assessment or ability to determine student's achievements (Busch et al., 2015), or as teacher's ability to accurately judge students' learning behaviour (Klug et al., 2016). Alternatively, assuming an instructional view, other authors argue that teacher's diagnostic competence can be defined as assessment for learning practices which provide information about students' mastery of relevant prior knowledge and skills within a teacher's education domain, as well as, student's preconceptions of ideas or misconceptions about the learning materials (Ketterlin-Geller & Yovanoff, 2009). On the other hand, in teacher education, some more comprehensive and valuable definitions of diagnostic competences have been considered. For instance, diagnostic competence is regarded as a teacher's ability to diagnose student's learning needs in terms of motivation, emotion and comprehension (Barth & Henninger, 2012). Also, recently, researchers in teacher education have defined diagnostic competence in teaching in a much more applicable and comprehensive way. That is to say, teacher's diagnostic competence has been defined in terms of three interrelated knowledge about diagnosis in teaching: the declarative-conceptual knowledge, strategic knowledge and conditional knowledge (Heitzmann, 2014; Heitzmann et al., 2018). The declarative-conceptual knowledge according to Heitzmann and her colleagues, refers to a teacher's knowledge on concepts and abstract principles about diagnosis in the domain, and how they relate to each other. On the other hand, teacher's strategic knowledge refers to a teacher's knowledge about procedures, problem-solving strategies and the heuristics. For instance, Heitzmann et al. (2018 p. 249) argued that "an example of strategic knowledge is demonstrated when a teacher implements the pedagogical approach of problem-based learning". Moreover, according to Heitzmann and her colleagues, conditional knowledge or procedural knowledge in this case refers to a teacher's knowledge about when, how and why a strategy should be applied in solving a diagnostic problem. Thus, with conditional or procedural knowledge, teachers have the possibility to incorporate underlying principles of solving problems.

Diagnostic competences in teacher education are important as far as teaching and learning process is concerned. As such, teacher's diagnostic practices are the main source of information for students as they evaluate their achievement and draw conclusions about their academic abilities" (Zimmermann et al., 2018). In this view, teachers are required to diagnose students' performance and obtain information so that they can make evaluation on students' academic achievements. Also, a set of diagnostic skills can be used by elementary and secondary school teachers to assess the levels of pupils' meta-subject competence in a particular subjects e.g. Mathematics, Physics, and the likes. Then, the available information can help teachers to plan for further actions and for individual student's meta-subject competence in science education (Khuziakhmetova & Naumovab, 2016). On the other hand, teachers need to develop diagnostic competences in order to gain information about students' learning basics, be able to recognize students learning requirements within the scope of social interaction, and to restructure their teaching styles, and support students individually basing on the obtained information through diagnosis (Barth & Henninger, 2012; Hoth et al., 2016). Although, we can consider the importance of diagnostic competence in teachers' education in various ways, in short we can consider it as a cause of action that a teacher can apply in classroom situations in order to obtain information valuable for their teaching practices. For instance, through diagnosis, teachers can obtain relevant information for their students, interpret this information, then select suitable opportunities for their learners and hence teach appropriately (Hoth et al., 2016). This implies that the classroom teachers need to use different sources of information and knowledge while diagnosing students' misconceptions during learning and teaching process.

According to Barth and Henninger (2012 p.50), the three possible information sources that teachers can use to make diagnosis of students learning prerequisites are: firstly, “situation dependent information” which refers to information source that originate from observable aspects of the teaching situations, for instance student-student interactions, student-teacher interaction or student’s interaction with learning materials. Secondly, the “personal or class specific information” which entails the information that originates from an individual learner or the class itself. Thirdly, “professional and experiential knowledge” which refers to information from teacher’s own experiences that they gain during the training programs as professional teachers. Furthermore, according to their model of receiving necessary information for diagnosis, Barth and Henninger (2012) argued that information valuable for diagnosis in the classroom can be obtained through interaction between students themselves, or with their instructor, or with the learning materials. The social aspect of a classroom is an important source of relevant information for diagnosis. In fact, teachers can obtain relevant information for diagnosis within individual students’ interactions because each one has unique characteristics and experiences. Thus through students in the class, teachers can obtain a lot of information that are useful for diagnosis. Thus teacher’s knowledge of students plays a major role in the process of obtaining relevant information for diagnosis.

Diagnostic competences among teachers or pre-service teachers can be developed in different ways. For instance, Heitzmann et al. (2018) explained three possible stages on which pre-service teachers can acquire diagnostics competence. Firstly, in the early stage pre-service teachers acquire conceptual knowledge on basic concepts and principles necessary for solving a problem in a particular domain. At this stage pre-service teachers usually attempt to solve a problem through weak methods by relating between problem scenarios and the current state of a problem. Then in the intermediate phase pre-service teachers start to reflect on how the acquired knowledge can be used to solve diagnostic problem. They do this through trial and error using the acquired knowledge and abstract strategies. In the advanced stage, pre-service teachers begin to solve problems as fast as possible with less errors through automation of knowledge structures which has been acquired and stored as schemas in the early stage. On the other hand, Klug et al. (2016) also proposed a three dimensional model for developing teachers’ diagnostic competences with regard to students’ learning behaviour, both at school and home. The model is characterized by new perspectives and it is cyclic in nature. That is to say, when the last phase is completed, the first phase begins and the process continues again. According to Klug and his colleagues, this model of teachers' diagnostic competence begins with pre-action phase where teachers involve in generating targets for diagnosis, acquire knowledge of methods of gathering information, and practice on how to avoid judgments biases that can influence diagnoses. The next phase for developing in-service teachers' diagnostic competences according to this model is practicing the actual diagnosis. This is an action phase where teachers make predictions about their students' learning behaviour, gather information necessary for making diagnosis and act systematically. Then in the later phase, the post-action phase, teachers give feedback to their students, plan to promote individual student's competence and teach them how to self-regulate in their learning behaviour.

2.1.3 Contrast of diagnostic competences in teacher and medical education

Although the concept of diagnostic competence is important in teacher and medical education, a diagnosis in teacher education context is fundamentally different from medical eduaction with respect to the subject that is diagnosed, and perhaps the specific knowledge that is needed in order to interpret observations and other information. While in medicine, a physician identifies the illness or diseases with the goal of providing an appropriate treatment for a patient (Mamede et al., 2014). In an elementary school or a high school, the subject of a diagnosis is more diverse and can be individual learning prerequisites of a student (Barth & Henninger, 2012), the performance of a student, or characteristics of own teaching (Vogt & Rogalla, 2009). Another obvious difference between a diagnosis in the medical and in the school context is the knowledge base that is involved in the diagnosis. Whereas in medical education, biomedical knowledge on pathological mechanisms that causes diseases is necessary for a successful diagnosis (Woods, 2007), for a teacher in a school, pedagogical knowledge about the development of competences is more fundamental (Baumert et al., 2010; Hill Rowan & Ball, 2005; Kunter & Baumert, 2006).

Despite the differences between a diagnosis in teacher education and medical education, there are also commonalities in the diagnostic activities that are part of a diagnosis in both domains. For example, in both domains a medical doctor or a classroom teacher makes hypotheses about possible causes of a problem. Then after generating the hypotheses, they collect data on the specific case with respect to the goal so as to verify or dismiss the hypothesis. Finally, they draw a conclusion and make a decision about the cause of a disease or learning pre-requisites of a student and plan to take action or make decisions (Fischer et al., 2014). Another, emerging similarity between the two domains seems to lie on how the expertise in making diagnosis during pre-service training programs. The literatures show that both in medicine and teacher education, expertise in making diagnosis develops roughly through three main phases (Heitzmann et al., 2018; Schmidt & Rikers, 2007). (1) The early stage where either a medical students or pre-service teachers acquire conceptual knowledge for solving diagnostic problems. (2) The intermediate or secondary stage where a medical student or student teacher begin practicing the acquired knowledge with real patients or students of their choice. This phase of diagnostic expertise is characterized with trial and errors where medical students or student teachers practice diagnosis using real cases or case scenarios. (3) The advanced or later stage where a medical student or student teacher stores the knowledge structures in terms of illness scripts or schema that is useful for solving problems in future as a result of automation. On the other hand, a diagnostic competence in medical domain is similar to that in teacher education based on the end goals of diagnosis (Fischer et al., 2014). Apart from core aims, the diagnosis process either in medicine or teacher education generally intends to obtain specific information about the observed characteristic for a patient or a learner. This information that is gathered can be used to determine appropriate treatment for a patient or to improve instructional strategy in a classroom, thereby facilitating conceptual change or reflection at teaching actions in teacher education context.

2.2 Operational definition of diagnostic competence

There are various ways in which the term 'diagnostic competence' can be defined according to domain or context and the purpose of diagnosis. However, in the context of this research project the term diagnostic competence is operationally defined in two different approaches: with respect to the first study (meta-analysis) and the second study (an emperical study). With regard to the first study: despite the differences in diagnosis process that might exist in medicine and teacher education, the following operational definition of diagnostic competence might be applicable in both domains; "diagnostic competence is the ability to successfully engage in the goal oriented gathering and integration of case specific information in order to make medical or an educational decisions" (COSIMA research group, in press). Thus, the search for studies that would qualify for inclusion in the meta-analysis would apply this operational definition. Then, with respect to the second study, the term 'diagnostic competence' has been operationally defined as declarative knowledge of concepts and procedures that pre-service teachers need to develop in order to identify pupil's misconceptions in specific topics or content areas of Physics. The second operational definition of diagnostic competence has been adapted from the three interrelated knowledge acquisition in both domains which were identified in terms of declarative-conceptual knowledge, strategic knowledge or conditional knowledge (Heitzmann et al., 2018; Stark et al., 2011). These knowledge categories have been practical with respect to empirical studies that were conducted to foster diagnostic competences in the fields of medicine and teacher education. Also, from these studies the declarative conceptual knowledge has been referred to as knowledge about the concepts and abstract principles that a medical student or pre-service teacher has to acquire in order to solve diagnostic problems. On the other hand, strategic knowledge is used when a medical student or pre-service teacher is actually trying to solve a problem while applying the concepts acquired before (Heitzmann, 2014; Heitzmann at al., 2018). According to Heitzmann and her colleagues (2018), the conditional knowledge in this case refers to knowledge of "why and when should the knowledge of concepts and abstract principles be used" (p.247). Then, the procedural knowledge on the other hand refers to the knowledge about procedures that pre-service teachers need to apply so as to solve diagnostic problems, for instance identifying pupil's misconceptions.

Moreover, other researchers have indicated that, the diagnostic competence is fundamentally based on learners developing conceptual and procedural knowledge (Schneider et al, 2011). However, for several decades, researchers in education have debated on whether young learners need to acquire procedural knowledge first before they learn about a particular concept, or the acquired conceptual knowledge among the learners can facilitate learning of procedures about specific concepts, the concept that can also be applied to learners at high education. Rittle-Johnson et al. (2001) argued that school children with greater conceptual understanding in Mathematics tend to have greater procedural skill although the acquisition of procedural knowledge does not necessarily lead to increased conceptual knowledge. According to Rittle-Johnson and his colleagues, learners at elementary schools can use their conceptual understanding to evaluate strategies or procedures which they have not yet applied in the learning process.

The relationship and contrasts between conceptual knowledge and procedural knowledge have been considered in different ways in the past few decades. Basically, the term conceptual knowledge can be referred to as the knowledge of abstract concepts or ideas generated from particular topic or content area. Some other authors refer to conceptual knowledge as a clear understanding of the principles and rules that govern a particular domain and relationship between knowledge structures in that domain (Rittle-Johnson & Alibali, 1999; Byrnes & Wasik, 1991). Rittle-Johnson and his colleagues further considered conceptual knowledge as the knowledge of concepts which is mostly characterized by interrelationship between ideas or concepts in specific domain. For instance, research on Mathematics have used the term conceptual knowledge to mean knowledge about mathematical concepts and their interrelationship (Rittle-Johnson & Alibali, 1999; Rittle-Johnson et al., 2001; Byrnes and Wasik, 1991). Furthemore, Byrnes and Wasik (1991, p. 77) argued that "conceptual knowledge has been characterized using several different constructs, including semantic nets, hierarchies, and mental models". On the other hand, procedural knowledge is used to refer to knowledge about knowing 'how' or concepts that learners need to apply in order to attain a specific goal (Byrnes & Wasik, 1991). Moreover, Byrnes and his colleague considered the term 'procedures' itself as constructs or skills, strategies, productions, or interiorized actions in the process of attaining a particular goal during the learning process.

2.3 Misconceptions in physical sciences

The term 'misconceptions' in physical sciences can simply be defined as an incorrect understanding of a scientific idea or a fact. Also, in physical sciences, a misconception can be considered as an alternative perception of the scientific ideas or factual information that students understand and make predictions about in the physical world we live in (Chin, 2001; Andre and Ding, 1991). These scientific perceptions about physical world are usually based on the students' experiences, or the way they perceive natural phenomena from childhood until when they come to school. Also, the perceptions usually show their understanding of the world but often they incorrectly represent the natural world (Andre & Ding, 1991; Smolleck and Hershberger, 2011). Thus, one of the fundamental causes of misconceptions in physical sciences is learners' understanding due to own experiences as he or she interacts with the physical world. As a result, learners at elementary, middle or high schools usually hold science misconceptions due to the false generalizations they make on some phenomena in the physical world or own beliefs (Stein et al., 2008; Demirci, 2005; Pine et al., 2001; Smith et al., 1994). Also, in one way or the other, parents or peers can contribute to these incorrect perceived notions which young learners can build up about particular science ideas in everyday life. That is to say, sometimes it happens that instead of parents or peers to provide the right answers to someone's personal inquiry about a particular scientific phenomenon, they tend to give wrong information to learners (Thompson & Logue, 2006).

On the other hand, science misconceptions among students can arise due to instructions that teachers or instructors provide at schools. Some of the instructors can guide learners to understand some scientific ideas in the wrong direction if they do not provide clear explanations during teaching and learning process at schools. Alternatively, some teachers or instructors themselves might have already possessed misconceptions on particular scientific ideas and therefore they can easily transmit them to their learners. For instance, it was found out that Physics teachers possessed similar misconceptions regarding gravitational force, magnetism and temperature that were similar to common students' misconception (Çıbık, 2017; Burgoon et al., 2010; Pardhan & Bano, 2001a). Another situation in which misconceptions in physical sciences can occur is the nature of the scientific idea itself that students have to learn at schools. Some science ideas or concepts are complex by nature. That is to say, they contain more abstractions in which students cannot grasp the correct concepts immediately. For instance, in Physics there are some ideas which appear to be more complex or abstract in such a way that when students encounter them they can easily misunderstand them. For example; consider a Physics idea about "whether something sinks or floats on water depends on a combination of its density, buoyancy, and effect on surface tension", then it is easier for students to understand that "things float if they are light and sink if they are heavy" a concept which is wrong (Thompson & Logue, 2006, *p*. 554). In fact this is a high abstraction that students can misunderstand due to the nature of the scientific idea itself. It is difficult for young learners to think of object's average density, buoyancy or an effect on surface tension that are the ones that lead into a ship made of heavy metal to float on sea. Therefore, it is easier for them to build up misconceptions in physical sciences when they interact with abstract ideas like these. Thus, misconceptions among young learners can arise due to peers, parents or poor instructions that they might receive during the learning and teaching process at schools.

Misconceptions in physical sciences fall into five categories according to Committee on Undergraduate Science Education, National Research Council (1997). These categories include: pre-conceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions, and factual misconceptions. A physical science misconception due to pre-conceived notions refers to popular science concepts which students note down due to every day experiences. Some science education researchers believe that students might come to classroom with false pre-conceived concepts about the physical world due to their own experiences (Minstrell, 1989), the notion that the Sun revolves around the earth may arise because young people might learn from experiences or from family members that the Sun rises from east in the mornings and sets off in the west during the evenings. On the other hand, misconceptions from non-scientific beliefs are views that students learn from sources other than scientific education e.g. the moon produces its own light because it appears bright like the stars in the night. A physical science misconception due to conceptual misunderstandings refers to incoherence between pre-conceived scientific ideas and new ideas which students learn at schools. These misconceptions arise when teachers teach students some scientific information in a way that it conflicts with students' correct pre-conserved notions or beliefs. This might also happen in schools when teachers fail to provide clear instructions that may cause students to end up with wrong scientific concepts. On the other hand, vernacular misconceptions arise from incorrect use of some common words that can be used in science and in other learning situations in social sciences. For instance, whereas in Physics 'Work' is done when a force causes a translational motion, in normal life the same term can mean an occupation. The final type of physical sciences misconception according to (Committee on Undergraduate Science Education, National Research Council, 1997) is factual misconceptions. These refer to preconceived ideas or notations about scientific facts since childhood to adulthood. For instance, students may understand the scientific fact that light can propagate only through matter while in fact it can propagate even through vacuum.

One of the bigest problem in teaching and learning physical sciences is existence of misconceptions among the learners. Some researchers have argued that if students' incorrect understanding of scientific ideas are not corrected as early as possible, they might hinder further learning of new ideas (Andre & Ding, 1991; Çıbık, 2017; Pine et al., 2001; Smith et al., 1994). That is to say, positive learning transfer will not occur because these existing wrong schemas will hinder the process of organizing new ideas. This is because educational psychology usually entails that learners need to organize new knowledge from the existing knowledge structures or schemas. For example; in Physics most of the concepts which students have to learn in middle and high schools depend on previous learned ideas. For instance, when students are supposed to learn about the concept of 'force' which acts on a moving object as a product of its mass and acceleration, first they need to understand clearly ideas about how acceleration is computed from velocity and time or an instant with which the force acts on a body. On the other hand 'velocity' is another typical example of dependent variable in Physics. The velocity of a moving object depends on the ideas of displacement or distance moved in a particular direction per given time. If during the learning process it happens that a student possesses misconception about how to determine displacement, then this will shift on how to determine velocity, and eventually this might be a problem on how to deal with acceleration, a physical quantity which determines a ‘force’ which acts on a moving object. This phenomenon applies not only in Physics but also in other physical sciences where students have to learn concepts that depend on the pre-existing knowledge about other fundamental concepts.

Misconceptions in physical sciences need to be identified by teachers or instructors so that they can facilitate conceptual change among the learners (Stein et al., 2008; Thompson & Logue, 2006). To do so, they need to use various strategies so as to know exactly which kind of misconceptions students possess due to any other factor. For several decades, researchers have used different strategies to identify common misconceptions which were held by their learners in lower and higher levels of education. Some of the well developed research tools for identifying common students’ science misconceptions are: structured interviews, deductive questionnaires and multiple choices tests (Guisasola et al., 2004; Gurbuz, 2015; Gurel et al., 2015; Schmidt, 1997; Sadler & Sonnert, 2016; Wind & Gale, 2015). Gurel and his colleagues argued that researchers need to develop different diagnostic tools so as to identify students’ misconceptions. According to their review on comparing and identifying tools that can be used to identify students’ misconceptions, they reveled that the most commonly used diagnostic tools are interviews, followed by the questionnaires in form of open ended tests, then the least is multiple choice tier tests. On the other hand, although interview schedules are easier to construct and administer,can collect in-depth information and is flexible to use, they are time consuming, not objective and require large number of participants to generalize the results. Questionnaires in form of open ended questions can cover a lot of contents in a topic, give chance for learners to respond even to ideas that teachers are not aware of, but may not be objective and give wrong information. Also, although multiple choice tests can save time and are easier to administer, can be scored objectively to large number of learners, and can give valid information about students’ misconceptions, they are difficult to construct. On the other hand, multiple choice tests can be constructed in a variety of ways additionally to ordinary or one-tier multiple choice tests. A multiple choice test can be constructed in form of two, three or four-tier tests according to Gurel et al. (2015). In this case, a researcher can construct a multiple-choice test that includes a second-tier in which a test item asks for the reason for choosing an alternative answer, and the third-tier in which a scale is included to ask for the students' confidence level for the given answers for the above two, and a four-tier in which the researcher can decide to find out more about the lack of knowledge for a particular item.

Other research instruments that teachers can use to identify students' misconceptions include: 'Science Beliefs Tests' and the online diagnostic tools or 'Diagnoser Tools' (DeBarger et al., 2011; Stein et al., 2008; Thissen-Rose & Hunt, 2004). The Science Beliefs Test according to Stein and his colleagues was originally designed to assess pre-service science teachers' beliefs about general science subject e.g. Chemistry, Physics, Biology, Earth Science and Astronomy at elementary level. This assessment tool consists of about forty seven 'TRUE/FALSE' that require students to incorporate explanations upon their responses. Moreover, Stein and his colleagues argued that science beliefs tests can help teachers to identify students' commonly held science misconceptions before they receive classroom instruction. On the other hand, observation can also be used as tool to detect students' misconceptions in physical sciences. For instance, one of the observational tool that can be used to assess students misconceptions is the 'predict-observe-explain or POE tool (Chin, 2001). According to Chin, POE tool can best be used for real classroom activities e.g. demonstrations when learners have some basic knowledge about a particular topic. Also, POE can help teachers to identify the deeply held science misconceptions beyond students understanding of facts and algorisms since teachers are able to observe how students are thinking, reacting to what they observe or ask questions as students make observations.

Teachers or researchers can also use online tools known as 'Diagnoser' to assess students' science misconceptions about the physical world. The Diagnoser tools have been designed by National Science Foundation in 2001 in order to help teachers or instructors to diagnose misconceptions that students might possess in physical sciences. Simplified, these tools contain a set of questions designed to elicit some kind of wrong conception of ideas for a particular topic or specific sub-topics in one of the science subjects. The Diagnoser Project tools have been developed under this project National Science Foundation, so as to support teachers to implement a diagnostic learning environment, and identify the most common misconceptions held by students in middle and high school sciences. These online resource materials can be found at: http://www.diagnoser.com/teacherapp/home, which is a free website that provides formative assessment and instructional tools for science teachers to use with their students according to FACET Innovations, LLC.

2.4 Misconceptions in Physics

A misconception in Physics can be referred to as student's incorrect or alternative understanding of Physics concepts due to various factors. For instance, in everyday life students usually encounter various physical phenomena concerning properties of matter in relation to energy. Due to these observations students usually build up some mental representations in order to interpret and understand these phenomena about the physical world (Chin, 2001; Guisasola et al., 2004). However, sometimes students do not provide correct explanations upon a particular physical world's behavior that is consistent with the laws and principles of Physics. As a result, they end up with false or alternative conceptions of ideas (Demirci, 2005; Chin, 2001; Pardhan & Bano, 2001b). Also, because of the lack of knowledge about these observations or less experiences, students perceive a particular phenomenon in a wrong direction that contradicts the known scientific facts and therefore hold up misconceptions. Thus, at elementary schools, high schools or even at the university level, Physics misconceptions are very common due to incorrect perceptions of phenomena about the physical world, or pre-conceived inconsistent notions compared to known scientific concepts and facts (Committee on Undergraduate Science Education, National Research Council, 1997).

On the other hand, pupils or students can hold-up some common misconceptions in Physics according to how they generalize some personal observations that they make from the physical world or their experiences. The inconsistent explanations on the behaviors of a physical world might arise from a student herself or himself because of interactions with peers or family members (Thompson & Logue, 2006). Then, as students go to school they experience new learning environments or because of the interaction with other students they might end up with wrong generalization of scientific ideas. However, occasionally they may receive incorrect instructions from teachers who also might have already held up some wrong scientific ideas or misconceptions with them (Burgoon et al., 2010). In fact misconceptions in Physics exist when a student has an incorrect understanding of a particular concept or thinking that deviates from well known Physics ideas. These misconceptions can be held by students not only at elementary or middle schools but also at high schools or even at university level. For example, when enrolled students in teacher education program at the university were asked to rate whether some selected items in physical sciences are true or false, some kind of false conceptions of physical science ideas were detected (Stein et al., 2008) in which some of these misconceptions were directly related to Physics subject. The findings obtained show that these pre-service teachers had prior incorrect beliefs or misconceptions for each of the five items used. According to Stein and his colleagues, the underrating to these misconceptions might provide teachers with useful information for improving instruction and hence facilitate their conceptual change. On the other hand, (Sadler & Sonnert, 2016) indicated some scientifically known concepts and their corresponding common misconceptions. These concepts were tested in a study to test two hypotheses regarding teacher's knowledge in middle schools physical sciences, and they were actually Physics misconceptions that are commonly held by students in middle or high schools. Table 1 shows some of the typical examples of Physics concepts and their corresponding common held misconceptions for sub-topics of 'motion and forces' and 'transfer of energy' according to Sadler and Sonnert, (2016, p.29).

Table 1: *Typical examples of some misconceptions in Physics*

- **Known Concept**: "*Forces can act in the direction opposite to an object's motion*".
  Misconception: "*A force is always in the direction of an object's motion*".

- **Known Concept**: "*Position can be used to present an object's motion*".
  Misconception: "*Objects that speed up cover the same distance per unit time*".

- **Known Concept**: "*An object's position, direction of motion, and speed are interrelated*".
  Misconception: "*Graphs of motion versus time are similar to the physical path followed by the object*".

- **Known Concept**: "*Light propagates and interacts with matter and it is passively detected*".
  Misconception: "*Light travels in a straight line even when it interacts with matter*".

- **Known Concept**: "*Electric current provides a means of transferring electrical energy where heat, light, sound and chemical changes are produced*".
  Misconception: "*Electricity behaves the same way as a fluid*".

2.4.1 Misconceptions in Mechanics

Mechanics is one of the most common content areas in Physics that teachers normally teach at middle or high schools in many countries. Also, most of the topics in Mechanics form a foundation on other core topics for example: Electricity, Optics, Heat or Temperatures, and Waves. Then through several decades researchers have identified common misconceptions that are held by students in Mechanics (Trowbrideg & McDermott, 1980; Trowbrideg & McDermott, 1981; Demirci, 2005; Smolleck & Hershberger, 2011). However, in Mechanics most of the common misconceptions occur in the following topics: force and motion, nature of force, energy transfer, and properties of matter. This is because students in many countries interact with these physical phenomena since their childhood. According to FACET Innovations, LLC (http://www.diagnoser.com), the following are sub-topics where misconceptions in Physics Mechanics for the topics of force and motion can commonly occur: position and distance, change in direction, determining speed, average speed and acceleration. On the other hand, nature of force comprises of the following sub-topics where Physics misconceptions in Mechanics can also arise. These include: gravitational force, magnetic forces and electric force. Also, in a topic of energy transfer students' might possess Physics misconceptions in the following sub-topics: gravitational potential and kinetic energy, thermal energy and elastic gravitational potential energy.

In the last decade, some organizations have organized facets of student's thinking or knowledge structures in manners that can help researchers and teachers to understand various Physics concepts and their corresponding misconceptions. Under FACET Innovations, LLC (2008) (http://www.diagnoser.com/teacherapp/home#resources/cluster/CL-1/FacetCluster), facets of student thinking and the facet clusters have been defined as "framework for organizing the research on student conceptions in a way that is understandable to both discipline experts and teachers". These frameworks include facets clusters that comprise of specific students' learning objectives arranged for different Physics sub-topics not only in Mechanics but also in other areas for instance: Electricity, Waves and Optics. As described earlier under these innovations, a full description and inventory of facets of student thinking and facet clusters is found at 'Diagnoser.com' website (http://www.diagnoser.com). Table 2 presents a typical example of the facet cluster for sub-topic of 'position and distance' in Physics Mechanics according to FACET Innovations, LLC organization.

Table 2: *Facet Cluster for position and distance sub-topic in Physics Mechanics*

00	For motion in one direction, students correctly identify the position of an object at several times and can correctly determine the distance traveled between two instants in time from the information given. The information may be given in graphs, tables, pictures, or words.	
	01	Position of an object is appropriately determined as a location with respect to a reference object or scale.
	02	The distance traveled (or changes in position) in a time interval for an object traveling in one direction is the difference between the initial position and the final position in that time interval.
30	The student incorrectly identified the initial position as zero.	
40	The student did not distinguish between the ideas of position and distance.	
	41	Position (or location) is determined by giving the distance traveled (or change in position).
	42	Distance traveled is determined by giving the final position.
60	The student determined distance by adding two or more positions during the motion.	
70	The student did not distinguish position and/or distance from speed.	
	71	Position is determined by reporting the speed.
	72	Distance is determined by reporting the speed.
80	The student interpreted a particular point on the position vs. time graph (or in a table) to mean no motion, (e.g., the object can't be moving if asked about one instant in time).	
90	Student viewed a position or speed graph as a map of the actual motion.	
	91	Student interpreted an upward (or downward) sloping graph to mean the object is going uphill (or downhill).
	92	Student interpreted a flat line on the graph to mean the object is moving on a flat surface.

Note. Source: http://www.diagnoser.com. The 0X and 1X facets are the learning goals. The facets that begin with the numbers 2X through 9X indicate ideas that have more problematic aspects.That is, the higher facet numbers, are the more problematic facets. The X0's indicate more general statements of student ideas. Often these are followed by more specific examples, which are coded X1 through X9.

2.4.2 Misconceptions in Electricity

Another area where learners encounter common Physics misconceptions especially in elementary schools is Electricity. The findings from various researches have indicated that there are a number of misconceptions about electric current that are not explicitly addressed by traditional teaching methods (Andre & Ding, 1991; Çıbık, 2017; McDermott, 1991; Shipstone, 1984). Usually, students at middle and high schools can hold these misconceptions about electric current due to limited experiences, misinterpretation of phenomena or beliefs, but it was once revealed that even students at higher education e.g. at university level held Physics misconceptions about simple circuits. For example, misunderstanding on how to rank three bulbs in simple electric circuit in-order of brightness was revealed in an investigation during regular course examination of university students who were enrolled in a large lecture section of calculus and algebra-based introductory Physics course (McDermott, 1991). According to McDermott, the following are some of the common misconceptions about electric current that student at the university can hold, and they have been identified by other researchers.

> *"Current is used up by the bulbs in a circuits; the battery is a constant current source; the direction of current, the order to the elements and physical placements of the elements all matter" (p*. 308*).*

Moreover, (McDermott, 1991) also observed that many students held misconceptions about simple circuits, Ohm's law and resistance to electric current. Also, students who were found to lack experiences with simple circuits which could draw up concepts to help them to relate electric current, voltage, and electrical resistance. Similarly, some studies were conducted to investigate misconceptions in Electricity. For instance, when school children were asked to answer two specific questions about electric circuit containing one battery and series of lamps (Shipstone, 1984b) some common misconceptions were identified. According to the analysis of their responses, four different children's models or misconceptions about flow of electric current were identified. Table 3 shows some typical examples of these commonly held electric current misconceptions according to (Shipstone, 1984).

Table 3: *Typical examples of common Physics misconception in Electricity*

Model I "*Current leaves the battery at both terminals and is used up within the circuit elements".*
Model II "*Current flows in one direction around the circuit, becoming gradually weakened as it goes so that later components receive less. Lamps furthest along the circuit in Figure 1 will be least bright".*
Model III "*Current is shared between the components in a circuit. In Figure 1*(p.186) *where the lamps are identical the current is shared equally so that they will all be of the same brightness. Here, too, the current is not regarded as being conserved".*
Model IV "*The scientific view is similar to model II, except that the current is the same throughout the circuit"*

Misconceptions about electric current and those ones associated with electrical resistance are common to most middle school children because they are too abstract. At this level, it is easier for learners to assume ideas according to what they observe, while, in reality some concepts are different from what we can see physically happening when electric current flows in circuit components. That is why misconceptions in Physics especially from Electricity are common at elementary and high schools. Likewise, university students have been found to possess some misconceptions about certain scientific concepts in Electricity. For instance, recently and in the last few decades, researchers (Çıbık, 2017; Andre & Ding, 1991) have revealed that university students also hold misconceptions in Physics that is related to the concepts of electric current, electric field, electromotive force and electric potential difference. In the study to investigate students' misconceptions, declarative knowledge, and stimulus conditions on student solution to a problem (Andre & Ding 1991) in basic Electricity, it was observed that students' performance was influenced by their knowledge of relevant declarative facts and the stimulus conditions of the experiment as well as by their models or misconception of the electrical situations. Also, recently Çıbık (2017) revealed that pre-service teachers at undergraduate level had several Physics misconceptions that are related to the concepts of current, electric field, generators, supply electromotive force, and electric potential difference. Furthermore, the author observed that student teachers enrolled for Physics courses were holding misconceptions about the function of magnetic fields and energy conversion in electric power-plants, a subject that deals with context of alternating current.

2.5 Diagnostic competence in Physics misconceptions

A science teacher needs to identify which kind of misconceptions students might possess before proceeding with an instruction in the classroom. This is because misconceptions can hinder learning of new science ideas if they are not detected and corrected before or during the lesson (Chin, 2001; Smith et al., 1994; Thompson & Logue, 2006). As such among the science teachers, Physics teachers need to develop sufficient diagnostic competence to effectively determine misconceptions that students might have already possessed or acquired during teaching and learning process. Therefore, diagnostic competence in Physics misconceptions can simply be regarded as 'teacher's ability to identify learners' false or alternative conception of ideas in a particular topic or content areas. With respect to the operational definition already given in previous chapters, diagnostic competence in Physics misconceptions can also be referred as the knowledge of concepts and procedures on how to identify pupil's misconceptions in Physics that teachers have to develop during professional training or even after the training.

However, in order to diagnose pupils' Physics misconceptions, teachers require some strategies for diagnosing them otherwise they will persist in the minds of students. Some of these strategies include the use of either classical or modern diagnostic tools. The classical diagnostic tools include: interview schedules, ordinary multiple choice tests, and questionnaires. Other classical diagnostic instruments which have been used to identify students' misconceptions include: observation schedule or inventories, one-tier multiple tests and open-ended tests. Among these classical diagnostic instruments some of them have been commonly applied in diagnosing learners' science misconceptions. For instance, interviews, open-ended tests and multiple-choice tests were found to be the most commonly used diagnostic tools to determine students' misconceptions in science education researches (Guisasola et al., 2004; Gurel et al., 2015; Schmidt, 1997). However, according to Gurel and his colleagues, interviews can enable researchers to gain in-depth information about misconceptions and they are flexible to use, although they require large amount of time and large number of participants in order to generalize the findings. On the other hand, the ordinary multiple-choice tests which are immediately scored and applied to a large number of students can be useful in diagnosing students' misconceptions, but they are difficult to prepare especially for novice teachers. Therefore, when applying these classical diagnostic tools Physics teachers should be aware that each one has its own strengths and weaknesses.

Some other modern diagnostic instruments have been designed in order to identify pupils' misconceptions in Physics. For example, the Four-tier multiple choice tests, the diagnostic tools which are comprised of items that combine all the advantages of two-tier and three-tier multiple choice items. These modern diagnostic tools are described as follows according to Kaltakci-Gurel et al. (2017, p. 240).

> "*A four-tier test is a multiple-tier diagnostic test. The first tier of it is an ordinary multiple-choice test with its distractors addressing specific misconceptions. The second tier of the test asks for the confidence of the answer in the first tier. The third tier of the test asks for the reasoning for the answer in the first tier. The fourth tier of the test asks for the confidence of the answer in the third (reasoning) tier*".

When these diagnostic tools were used to assess misconceptions in Physics, they were found to be valid and reliable instrument in assessing misconceptions in the topic of geometrical optics (Kaltakci-Gurel et al., 2017). Therefore, compared to classical diagnostic tools which were used by researchers to identify students' misconceptions, these modern online instruments were found to be reliable and can be used by Physics teachers flexibly. They can also be used by students in a wider range when compared to classical diagnostic tools which might not be flexible due to the nature and the way they can be used. However, in the last few decades, some other online diagnostic tools have been used by classroom teachers in order to determine students' Physics misconceptions. One of these online tools is 'Science Beliefs Test' which is an online diagnostic instrument which comprise several statements that require students to assign either true or false responses upon the items, and in addition they request written explanations to accompany these responses (Stein et al., 2008). The aim is to avoid guessing the right answer filling the test as can occur with ordinary multiple choice tests. Thus, with 'Science Beliefs Test' it is possible for a Physics teacher to determine students' commonly held misconceptions.

The other online diagnostic tool that might be useful for teachers to identify common misconceptions held by students in Physics, and even in other science subjects are: the 'Diagnoser' tools. These online tools have been designed by National Science Foundation in 2011 in USA in order to help science teachers to diagnose misconceptions that students might possess in science subjects: Physics, Chemistry and Biology. Simplified, these diagnostic tools contain a set of questions designed to elicit wrong or alternative conception of ideas for a specific topic in one of the science subjects. The Diagnoser project tools have been developed under this project by National Science Foundation so as to support teachers to implement a diagnostic learning environment, and identify most of the commonly held science misconceptions by students in middle and high schools. These online resource materials can be found on: http://www.diagnoser.com/teacherapp/home, which is a free website that provides formative assessment and instructional tools for science teachers to use with their students.

In the learning process, Physics teachers need to acquire knowledge and skills about how to identify pupils' misconceptions due to several reasons. One of the reasons is to facilitate conceptual change among students (Morrison & Lederman, 2003; Pine et al., 2001; Smolleck & Hershberger, 2011). Students' false conception about Physics ideas must be identified and corrected before they became resistant to learning of new ideas. Although there are a number of ways in which Physics misconceptions might be acquired by students, Physics teachers need to acquire diagnostic competences so as to regulate them. As such, conceptual change is fundamental to effective learning of Physics because the subject has many interrelated ideas which require students to understand them in order to avoid further confusion.

Also, Physics teachers require developing diagnostic knowledge in identifying pupils' misconceptions in order to facilitate the learning of new science ideas. This is because if pupils' misconceptions are not detected as early as possible, they might interfere with learning of new Physics ideas as students proceed with further instruction in the classroom (Smith et al., 1994). Thus, Smith and his colleagues argued that misconceptions can interfere with learning of more advanced ideas if they are not detected and corrected. Also, according to the authors, misconceptions can disagree with the concept of constructivism; a learning philosophy which is strongly emphasized in science education. Also, as a part of continuous assessment, Physic teachers need to detect students' misconception in order to understand how they learn and predict their performance in the classroom or in future (Kaltakci-Gurel et al., 2017; Klug et al., 2016). Furthermore, because misconceptions might be resistant to change and hinder learning of new science ideas, Physics teachers must be aware of these false conception of ideas, and be able to to diagnose and correct them (Gurel et al., 2015). The next chapter presents an overview of instructional strategies and approaches with respect to diagnostic competence.

CHAPTER THREE

INSTRUCTIONAL STRATEGIES FOR ENHANCING DIAGNOSTIC COMPETENCE

3.0 Introduction

This chapter describes the review of instructional strategies, the relationship between instructional approaches vs. the learning process, and instructional approaches in relation to learners' prior knowledge. Fuerthermore, it describes the concept of cognitive load in relation to instructional approaches.

3.1 Overview of instructional strategies

In this sub-section, the meaning of the term 'instruction' is first described briefly so as to guide the definitions of the terms: instructional strategy and instructional method or approach. Then, the distinction between instructional models, strategies, methods and techniques is also discussed briefly. The properties of instructional strategies are also described in details according to different perspectives. Then, finally the taxonomy of instructional strategies is described with respect to instructional approaches.

The term 'instruction' can be considered both in simple and broad views. Simply, instructions is considered as procedures that teachers plan and follow during teaching and learning process in order to achieve a particular learning objective (Akdeniz, 2016; Mayer, 2003; Smith & Ragan, 1999). According to this simple view, instruction is defined as a deliberate action that the teacher takes in order to facilitate learning. In a broader view, instruction can be defined as the whole process of facilitating teaching and learning, or the whole process of guiding plans for learning (Akdeniz, 2016). According to Akdeniz, the term instruction is strongly connected to the process of teaching and learning. That is to say, all the procedures and plans that teacher carries out in a classroom so as to facilitate learning are termed as instruction. Thus, Akdeniz (2016) argued that in any community at least everyone is an instructor because she or he instructs either by telling, showing or pointing out something to another person in order to facilitate learning. For instance, parents instruct children by telling and showing, while, experts in the field of medicine or engineering instruct by showing or pointing out important concepts or techniques when they offer apprenticeship to their inexperienced experts. Moreover, professional teachers at elementary or high schools instruct pupils in a classroom so as to help them to learn, while lecturers at universities instruct students during lectures. Thus, teachers or instructors give instructions to their learners or students in order to facilitate the learning process.

After brief discussion about the meaning of the term instruction, now let us have insights on the terms: instructional strategy and instructional method by first looking at instructional models. An instructional model is a broader term than instructional strategy, method or a technique. According to Saskatchewan Education (1988) an instructional model represents the broadest level of instructional enterprise and presents a philosophical orientation to instructions that teachers would carry out to facilitate learning. For instance, behavioral model, cognitive model, social learning model and the likes are some of the known instructional models. A model can be used to select an instructional strategy, a method (an approach), or a technique. Then, the term instructional strategy can be considered as procedures or plans that a teacher or an instructor carries out in order to attain a particular instructional objective (Akdeniz, 2016; Kanuka et al., 2007; Mayer, 2003). Moreover, within a particular instructional model various instructional strategies can be determined e.g. direct strategies or indirect strategies. Then, within a particular instructional strategy teachers or instructors can select different teaching approaches or methods, and within an instructional approach a teacher can use various techniques. A technique in this case refers to a specific instructional behavior that teachers use along with a particular instructional method or an approach in order to facilitate learning (Saskatchewan Education, 1988). For example, questioning, discussing, explaining, feedback giving, demonstrating are some of the teaching techniques.

The selection of instructional strategies depends on several factors according to the literature. For instance: curriculum requirement of a particular country's education system, the learning theories underlying different psychological models, what instructors and students believe about teaching and learning process, and last but not the least, the learning styles of the learners or students (Saskatchewan Education, 1988). The curricula are designed for different purposes in many countries and so they should guide instructors to select ways in which they can give instruction. Also, there are many learning theories outlined in psychology (e.g. behavioral, cognitive, or social learning theories) in which they determine the way how an instructor has to select a strategy. Another important school of thought is how teachers and students believe about learning process. This refers to philosophical ideas that also guide instructors to select strategies according to their beliefs. On the other hand, students also have different learning styles and different individual learning needs. These entire factors are then assumed to guide teachers or instructors in selecting a particular teaching strategy.

The literatures also show that there are many ways in which instructional strategies can be classified according to learning theories or models. For instance, instructional strategies have been classified as: direct instructions, indirect instructions, experiential learning, interactive instructions, or independent study (Saskatchewan Education, 1988). According to Saskatchewan Education, direct instructions are teacher-centered, deductive in nature and can apply examples to illustrate concepts, and in most cases are employed by instructors in elementary and middle schools. Also, they can be used for development of initial skills e.g. in higher education. The direct instructional strategies are not intended to develop higher level of cognition or competence and do not encourage interpersonal skill. Examples of instructional methods or approaches that comprise of direct instructional strategy are: lecture, didactic questioning, direct teaching, drill and practice, demonstration, and the likes. On the other hand, indirect instructional strategies are learner or student-centered, intended to develop higher order learning outcome, and can foster creativity and develop interpersonal skills among students. Examples of instructional methods or approaches that comprise of indirect instructional strategy are: problem solving, inquiry learning, discovery learning or induction, project, and the likes. Moreover, educators believe that within indirect instructional strategies the role of a teacher shifts from an instructor to a facilitator.

Furthermore, Akdeniz (2016, p. 63) argued that instructional strategies can also be classified based on a number of factors. For instance, when selecting instructional strategy, a teacher has to think of questions such as: “who is the focus of the instructional activity, what methods and techniques have to be applied in the learning process, how is information processed by learners, and based on what learning models?”. Also, according to Akdeniz (2016, p. 64) instructional strategies can be classified into four main taxonomies.

i. *Traditional taxonomy*, classification of instructional strategies based on learning models that emphasize that teachers provide instructions through presentation, discovery, inquiry learning, or co-operative learning.
ii. *Popular taxonomy*: classification of instructional strategies based on some properties for instance, Bloom’s taxonomy (recall, comprehension, application, analysis, evaluation, and synthesis).

iii. *Cross disciplinary taxonomy*: instructional strategies are classified according to different disciplines for instance, personality and instruction, neurosciences, and the likes.
iv. *Activity-based taxonomies*: instructional strategies are classified based on effectiveness in the instruction process and the consideration of specific instructional objectives (e.g. reasoning, performance, collaboration, and the likes).

3.2 Overview of instructional approaches

The term instructional approach in pedagogy can be used synonymously with the term instructional method. However, both terms refer to a plan that a teacher or an instructor follows in order to achieve a particular instructional objective (Kanuka et al., 2007; Mayer, 2003). For instance: lecture, direct teaching, problem solving, example-based learning, discovery or inquiry learning are some of the commonly known instructional approaches in pedagogy. An instructional strategy is used to determine a method or an approach. According to Saskatchewan Education (1988), an instructional method is a plan or procedure which is used to create learning environment and specify the nature of the learning tasks that the teacher and learners have to follow during the lesson. Additionally, Kanuka and his colleagues contended that an instructional method is a deliberate plan of actions in which teacher's role and students' activities are specified with respect to a particular learning outcome. Although instructional strategies are used to determine instructional methods or approaches, some of the approaches may cut across several strategies. For instance, while direct instructional strategies can employ examples to illustrate a particular concept; also indirect instructional strategies can apply examples before learners are actually involved in inquiry learning or solving a problem.

Another example which show that instructional methods can cut across different instructional strategies is seen from Table 2.2 (Akdeniz, 2016, p. 64) for classification of instructional strategies. According to instructional strategies classification table and the authors (e.g. Edvantia, Eristi & Akdeniz, and Bazan) as cited in Akdeniz (2016, p. 64), in this table instructional methods such as modeling, role play and simulation can be found in macro or focus strategies category (strategies that actively engage students into learning task) and also in micro or process strategies (strategies that engage students in higher order thinking). Also, while presenting or projecting, instructional methods can be found in higher order thinking strategies, they can also be found in cooperative or independent instructional strategies. Moreover, the author Bazan as cited in Akdeniz (2016, p. 64) showed that while discussion methods and brain storming can be classified into student-centered instructional strategies, these methods can also be found in teacher-centered strategies. Also, Saskatchewan Education (1988) indicated various instructional strategies where some instructional methods or approaches can cut across more than one category of an instructional strategy. For instance, while modeling approaches can be found in direct or indirect strategies, at the same time they can be found in experiential instructional strategies category. Also, while demonstrations and question-answers approaches can be categorized as direct strategies they can also be categorized as interactive strategies. The role played on the other hand can be found in both interactive strategies and experiential strategies, while field trip, simulations, and project can cut across indirect, experiential and independent strategies. Therefore, from these few examples, we can argue that various instructional methods or approaches can cut across more than one category of an instructional strategy.

3.2.1 Learning from direct instruction approaches

Direct instruction approaches are the most commonly used methods of teaching throughout several decades. This approach has been used in elementary or even in high schools to teach pupils via some techniques (e.g. questioning or explaining ideas). Direct instruction methods also have been used in higher education for instance during the lectures (Winarno et al., 2018). Moreover, Winarno and his colleagues have defined direct instruction approaches as procedures in which a teacher demonstrates knowledge and skills to students step by step, while at the same time allowing students to practice the learned concepts or skills, and finally gives feedback. On the other hand, Magliaro et al. (2005) contended that direct instruction is an instructional model that focuses on the interaction between an instructor and the learners. However, when the term direct instruction is used by researchers without specifying the meaning, it can easily be confused by readers because it can also be used synonymously with other terms like direct teaching or explicit teaching (Rosenshine, 2008). Furthermore, Rosenshine (2008, p. 1) described five definitions of the term direct instruction according to different contexts as follows: direct instruction refers to (a) “academic instruction that is led by a teacher regardless of the quality of the instruction” (b) “procedures that were used by effective teachers in the teacher effects research” (c) “procedures used by teachers when they taught cognitive strategies to students” (d) “procedures used in arithmetic and reading programs” or (e) “procedures where direct instruction is portrayed in negative terms e.g. settings where the teacher talks while students listen passively". Although, different meanings of the term direct instruction have been given with respect to different contexts, there are common characteristics of this approach that can overlap all the given meanings. These include: teacher guiding practices, students actively engaged in a lesson and teacher directing the learning activities. According to Rosenshine (2008), these common elements can be used to reduce the difficulty of the task during initial practice (e.g. present new material in small sections), provide scaffolds and support (e.g. modeling the procedures), provide supportive feedback or extensive students' independent practice.

Moreover, other authors have described direct instruction as an approach where the subject matter is delivered face-to-face by a teacher or an instructor by sequencing the learning materials deliberately (Winarno et al., 2018). According to other authors, direct instruction approaches can be used with large group of students making it a cost effective method of instruction for some skills (Cadette et al., 2016), can be used for each higher level cognition tasks e.g. developing process skills (Mansyur & Darsikin, 2016). On the other hand, direct instruction approaches have been critically described as inappropriate methods of teaching because they can cause students to be passive during the lesson, a teacher becomes an authoritarian person, or results into fact accumulation in the expense of thinking (Rosenshine, 2008). Also, when direct instructional approaches are used during learning task, they may result in low creative thinking and team work competences among the students (Winarno et al., 2018). Additionally, Saskatchewan Education (1988) pointed out that direct instructional approach can limit the development of higher order competences among students, attitudes required for critical thinking, and skills for interpersonal or group learning. When compared to other teaching methods, direct instruction approaches were found to be less effective in enhancing learning e.g. in the study to compare direct instruction and problem-based models, it was found that problem based approaches were more effective in improving students' mathematical skills than direct instruction (Firdaus et al., 2017; Winarno et al., 2018). Apart from several critics (Kuhn, 2007), direct instruction approaches have been used in elementary schools to implement curricula with students showing higher achievement especially in science subjects, to teach large group of students with time being reduced when compared to indirect approaches, and can be effective if they are used in conjunction with other method e.g. problem solving. Also, it was found that learning from direct instruction can be enhanced with other practices for instance, self-regulated tasks (Glogger-Frey et al., 2017). Moreover, while there was no significant difference regarding learning achievement between groups of the students who were taught Physics through jigsaw and cooperative instructional methods, when other variables were controlled, direct instruction had a facilitating effect on students' performance in Physics (Hänze & Berger, 2007).

3.2.2 Learning from example-based learning instruction approaches

Example-based learning approaches entail learning from examples or by observing other people when they perform a particular learning task. Learning from worked-examples involve learners through didactical steps towards a solution for a specific problem, whereas, learning by observation involve learners seeing another person performing a task facilitated by physical demonstration of a task by an expert, watching videos, using multimedia facilities for instance animations or a model telling a story (van Gog & Rummel, 2010). As such, the literature explains that example-based learning has been studied from either social or cognitive perspectives. As a cognitive endeavour, worked-out examples provide learners with didactical solutions towards a problem, while social learning endeavour provide learners with modeling examples, that is, an opportunity of seeing an expert or a model performing a learning task (Atkinson et al., 2000; van Gog & Rummel, 2010; Renkl et al., 1998). Therefore, example-based learning approach comprises learning models that describe learning process from either worked-examples or modeling examples. The worked-examples model usually is applied in classroom instruction to provide learners with written out steps on how to solve a problem, and it is more applicable with well structured learning activities. On the other hand, written examples can be used as modeling examples (van Gog & Rummel, 2010) because in studying, the learners observe how to solve a problem.

According to various research findings, example-based learning approach has the following advantages when compared to other instructional approaches: first of all, example-based learning approach can eliminate the weaknesses that are associated with conventional problem solving, for instance, high cognitive load which can be imposed through solving conventional problems (Sweller et al., 1998). Also, learning from worked-out examples can be effective for novice learners or beginners when it is employed, and saves time during the learning activity (Paas et al., 1994). Moreover, example-based learning approach might be more effective than the discovery learning procedures; learners can use worked-out examples as models to solve problems, and can be effective to learners with low prior knowledge especially when they are confronted with early skill development tasks (Renkl et al., 1998; Renkl et al., 2000; Tuovinen and Sweller, 1999). When examples are well designed and used in the learning activity, they can reduce the total amount of cognitive load that would be experienced by learners in overcoming the poorly designed instructions.

On the other hand, some weaknesses of example-based learning instructional approach have been identified. Although, example-based learning approaches have been effective in enhancing learning than other approaches, they do not guarantee students to change their learning behavior because there might be some other factors that affect the learning process (Atkinson et al., 2003; van Gog & Rummel, 2010; Renkl et al., 2000). For instance, if worked-out examples involve many interacting elements so that learners have to associate them at the same time during the learning exercise, learners might incur large thinking capacity and hence increase unnecessary cognitive load. Likewise, learning through modeling examples may hinder learning if the model's or expert's behavior are not well handled, for instance the way of dressing, language use or personal behavior that can interfere with the learning task. Also, if worked-out examples are used with more experience learners, they might become redundant because at this stage they can solve problems without much guidance (Sweller et al., 2003). Moreover, the over use of worked examples may hinder thinking capacities of learners to solve related problems (far learning transfer) and hence become too dependent on example to a situation in which they can think of a solution. Example-based learning can also cause stereotype way of solving problems because learners might not be able to think of alternative solutions (Sweller et al., 1998). Therefore, apart from the strengths of example-based learning instructional approach which have been identified, instructors need to understand some weaknesses of this approach when they plan to use it.

3.2.3 Learning from problem solving instruction approaches

For several decades problem solving instructional approaches have been used in training programs especially with advanced learners. This is because they require learners to solve problems through thinking or cognitive skills (Mayer 1998; Schmidt et al., 1996). Simply put, we can define problem solving as an approach for which learners learn by solving problems. According to cognitive architecture of instructional design, solving a problem in this case may demand learners to either arrive at the fixed solution (goal-oriented problem) or to provide as many solutions as possible (goal-free problem) according to the design of instruction or learning materials (Sweller et al., 1998). According to Sweller and his colleagues, most of the problems in structured domains such as Mathematics, Physical Sciences, Computer Science, and the likes apply means-end analysis problems so as to achieve a particular solution to a problem. Moreover, goal-oriented problems solving is more focused to specific solutions and can be applied to help learners to learn new skills easily. They might also be less time consuming and can help educators to cover a wide range of topics in a short time. On the other hand, the goal-free problems may be beneficial to situations in which learning is intended to gain general knowledge through problem solving skills (Sweller et al., 1998). Thus, this kind of instructional approach might enable highly knowledgeable learners to advance their knowledge in a specific domain.

In a wider point of view, problem solving is an instructional approach within problem-based learning approach. Some researchers have argued that problem-based learning approach has long history and has been applied in advanced learning curricula and has gained acceptance in multiple disciplines e.g. medicine (Savery, 2006; Dochy et al., 2003; Schmidt et al., 1996). Furthermore, Savery (2006) argued that learning from problem solving is an instructional approach that encourages learner-centeredness strategies which can empowers learners to conduct research, integrate theory and practice, and apply new knowledge and skills to develop practical solutions to a given problem.

Problem-based learning is the method of learning in which learners interact with problem solving problems with no solutions, learners work collaboratively, and they are responsible for their own learning, self-directed in the learning process, and an instructor acts as a facilitator to provide guidance for solving problems (Hmelo-Silver, 2004). Moreover, Hmelo-Silver argued that problem-based learning approach differs from other instructional approaches through a number of features. For instance, learning from problem solving encourages knowledge construction through constructivism, active learning and transferrable learning, and it can enhance intrinsic motivation especially when learners are able to solve problems on their own. The literature show that problem-based learning approach can be suitable for learning outcomes, for instance, science-based project where learners need to learn and apply the acquitted theoretical knowledge into real world problem solving (Hiebert et al., 2016; Merrill, 2002; Savery, 2006). Moreover, learning from solving problems empowers learners in the learning process through active learning, enabling learners to integrate theory into practice e.g. research-based projects, and apply the knowledge gained in the class to solve real life problems. Mayer (1998) argued that students need about three knowledge skills in order to solve problems. These include: cognitive skills (e.g. components in information processing), meta-cognition skills (e.g.

strategies for reading comprehension, writing and Mathematics), and motivational skills which comprise interest, self-efficacy and appreciation.

However, in order to solve a real problem, students require incurring higher order of thinking skills and it can be time consuming. The literature shows that students may need to follow a process cycle which begins with identification of a problem, throughout other processes to a conclusion which might lead into re-defining the problem again (Hmelo-Silver, 2004). For instance, Hmelo-Silver (2004) argued that in real problem solving, usually learners are provided with problem scenario in which to solve a problem probably they will follow a cycle (see Figure 1, Hmelo-Silver, 2004, p. 237). Under this cycle, learners begin the process by studying a given problem and identify all the possible facts about the problem. In other words, this refers to problem analysis. They can do this individually or collaboratively. Then, they think of possible solutions by formulating the hypotheses before they assess their assumptions. The evaluation of hypotheses will result in deciding whether they have knowledge enough to help to solve the problem or they need to consult other sources. This is a point where a facilitator can play a role here by guiding learners on how and where they can identify the knowledge required to solve a problem. The facilitator can also assist students by providing them with any support resources e.g. learning materials, worksheets, and so on. Then, the learners apply the available knowledge to solve a problem in which they can generalize solutions immediately without delay. This is a point where learners can start making abstractions or conceptual understanding about a problem, or generate new assumptions or hypotheses or identify facts about a problem. The whole process according to Hmelo-Silver is cyclic in nature.

3.3 Relationship between learners' prior knowledge and instructional approaches

There is close relationship between learner's prior knowledge (expertise) and the instructional approaches. Thus instructors need to consisder learners' prior knowledge when selecting instructional approaches. The literature suggests that learners' prior knowledge in a specific domain can negatively or positively influence the acquisition of new knowledge or information. That is to say, learner's prior knowledge can either hinder the learning of new information if it is inaccurate, incomplete or misleading; or promote the learning of new information if it is accurate and not misleading (Thompson & Zamboanga, 2004). Furthermore, Heitzmann (2014, p.23) explained a model for which either positive or negative learning transfers may occur among students as a function of existing knowledge. According to Heitzmann, positive learning transfer occurs when the existing knowledge helps a learner to learn new knowledge, while a negative learning transfer occurs when existing knowledge hinders learning of new knowledge. For instance, it was reported that highly knowledgeable readers performed better on the open ended questions than the low knowledgeable text readers (McNamara & Kintsch, 1996) whereas, also in a study to investigate whether prior knowledge was a predictor of students' achievement in psychology course (Thompson & Zamboanga, 2004), the domain prior knowledge had positively facilitated the learning of course information in psychology. Also, in a study to investigate the effect of two reading strategies that were followed by text readers on their learning performance (Salmerón et al., 2006), it was found out that coherence strategy and interest strategy affected learning differently as a function of the reader's prior knowledge. According to Salmerón and his colleagues, the coherence strategy supported learning better than interest strategy for low knowledgeable readers, while for intermediate knowledgeable readers, both strategies benefited readers equally. Thus, instructors need to consider the level of knowledge or expertise that learners possess in a particular domain when designing instructions because their prior knowledge can have positive or negative consequences in the learning process.

On the other hand, some researchers have revealed contradicting findings regarding the influence of different instructional approaches applied in the learning process on learners' performance in relation to learners' prior knowledge. For example, trainees with low prior knowledge benefited much more from worked examples than similar trainees who solved problems in a study to investigate the interactions between learners' prior knowledge in a domain and levels of instructional guidance (Kalyuga et al., 2001). That is to say, worked-out examples were redundant in the learning process with trainees who were much experienced or had high prior knowledge. This observation can also be addressed to the 'expertise-reversal effect' explained by Sweller et al. (2003) who argued that those instructional approaches which are effective to learners with low prior knowledge may be ineffective or even have negative consequences when they are used by learners with high prior knowledge. To explain these observations, researchers in cognitive researches contended that the level of learner's experience in a particular domain basically influences the extent at which schemas can be automated or retrieved into human working memory in order to organize the current knowledge or information (Sweller et al., 2003; Kalyuga, 2007). According to Kalyuga and his colleagues, inexperienced learners may have less schema to process new information, and so they may require much instructional guidance in order to learn the new information, while, with experienced learners, less instructional guidance is required because their rich schema may provide necessary support for them to learn new knowledge.

Also, in their study to explain the effect of redundancy effect Mayer et al., (2001) revealed that students who received extra learning materials (concurrent on-screen text) that summarizes or duplicated the narration, performed poorly when compared to those who received no on-screen text learning materials. The redundancy effect here caused the students to split their visual attention between the two sources of learning materials. The findings from another study to compare two learning approaches: the discovery learning (exploration and work-out examples) on how to use data base program, Tuovinen and Sweller (1999) revealed that students who had low prior knowledge with the data base benefited much more from worked examples when compared to exploration approach. However, when students were familiar with the data base, the type of instructional approach made no significant difference with respect to their learning because student who used discovery learning were able to draw up existing schemas to guide them in the discovery learning. On the other hand, Kalyuga et al. (2001) argued that instructional designers should take into account different levels of prior knowledge among the learners when selecting instructional approaches. Moreover, Kalyuga and his colleagues proposed that worked out examples may be used in the initial stage of learning in a particular domain, then as the learners become more knowledgeable with the domain, problem solving approaches can be used to advance the knowledge acquired initially. Likewise, Renkl and Atkinson (2003) proposed a smooth transition of instructional procedures in which problem solving is integrated with example-based learning based on the analyses concerning cognitive load and instructional approaches.

3.4 Additional instructional support in developing diagnostic competence

Most of the empirical studies that attempted to foster the development of diagnostic competences in the field of medical or in teacher education have applied a particular instructional approach during the leaning phase of an intervention. Problem solving or example-based learning are typical examples of the instructional approaches employed during the learning phases of an intervention. However, some other instructional procedures were used to enhance learning of how to diagnose additionally to the given instructional approach. For instance, in teachers education, a study on developing and evaluating a training program to foster teachers' diagnostic competences on students' learning behavior has been conducted (Klug et al., 2016). In this study, the semi-standardizes diaries were used additionally to problem solving instructional approach among teachers in one of the experimental group so as to self monitor their implementation of diagnostic actions. According to their finding, diaries had no interventional effect above and beyond the training program. Also, the influence of error explanation prompted adaptable feedbacks when used additionally to example-based learning approach on enhancing pre-service teachers' diagnostic competences (Heitzmann et al., 2018). The findings show that error-explanation prompts had positive effects on the declarative-conceptual knowledge when they are integrated with adaptable feedback, but error-explanation prompts alone hindered the learning of practical diagnostic knowledge.

In medical education, the effect of erroneous examples against correct examples, or elaborated feedbacks against knowledge of results feedbacks were used additionally to worked-examples in order to develop diagnostic competences of medical students within the context of web-based learning environment (Stark et al., 2011). In their first study, Stark and his colleagues revealed that erroneous examples were effective on enhancing diagnostic competences when they were combined with elaborated feedback with regard to the outcome measure of strategic and conditional knowledge. Likewise, in their second study they elaborated that feedbacks supported learning of all aspects of diagnostic competences especially the conditional knowledge. Also, the influence of self-explanation prompts on learning how to diagnose via clinical cases was investigated with or without generating self explanations (Chamberland et al., 2011). The findings obtained show that medical students who practiced diagnosis through self-explanations (experimental condition one) demonstrated better diagnostic performance than those who were in control condition on subsequent clinical cases concerning less familiarity topic; but one week later after the intervention. Similarly, a study to investigate whether the provision of self explanation prompts and adaptable feedbacks in addition to worked examples integrated with errors can foster diagnostic competences of medical students in a computer supported learning environment was conducted (Heitzmann et al., 2015). According to Heitzmann and her colleagues, worked examples that are integrated with errors, the provision of self-explanation prompts and adaptable feedbacks seem to be useful in developing diagnostic competences in terms of decision-oriented aspects, while, additional help to simulate reflection about errors by self-explanation had no effect.

Another category of instructional approaches that were used to enhance diagnostic competences in addition to the given instructional approach was structured or modeled reflections. For instance, the effect of structured reflections as compared to the generation of immediate or differential diagnosis on learning how to diagnose using clinical cases among medical students were investigated (Mamede et al., 2012; Mamede et al., 2014). The findings obtained show that structured reflections while practicing diagnosis with cases appeared to foster medical students' clinical knowledge more effectively than the generation of immediate differential diagnoses, and hence it seems to be an effective additional instructional approach. Also, the study to investigate whether the additional instructional guidance to worked-examples increased the benefits of reflections on learning how to diagnose by comparing the effects of free, cued and modeled reflections was conducted (Ibiapina et al., 2014). As a result, Ibiapina and colleagues found out that modeled examples of structured reflections enhanced learning more than the free or cued reflections; and according to them structured reflections might be the a useful additional instructional strategy for teaching clinical reasoning.

Generally, the literature indicates that some specific instructional methods have been applied during the learning phases of interventions to foster diagnostic competences in medicine and teacher education. However, in order for the learners to learn more effectively how to do diagnosis in both fields, researchers have used other instructional approaches in addition to the given instructional approaches so as to maximize the learning outcomes. To sum up, some of these additional instructional support measures include: the use of erroneous examples against correct examples, elaborated feedbacks against knowledge of results, structured reflections in comparison with modeled reflections, differential or cued reflections, and adaptable feedbacks with errors integrated into work-out examples. However, the literature indicates that, while most of these additional instructional support measures have facilitated the development of diagnostic competences effectively, some of them had no effects or had hindered the learning process of how to diagnose in both domains.

3.5 Cognitive load

The concept of cognitive load is important as far as cognitive learning theories are concerned. As such, cognitive load has been perceived as a multidimensional construct which represents the load that is imposed on the cognition system of a person, for instance when she or he is performing a particular learning task (Paas et al., 1994; Sweller et al., 1998). The cognitive load is further conceptualized as a construct that comprises of causal and assessment factors, of which both affect the cognitive load, and those factors which are affected by cognitive load itself.

According to Paas et al. (1994), the causal factors include: environmental characteristics or demands of the task, characteristics relating to the subject and the interactions between them. Therefore, in this case a causal factor is a function of three dimensions namely: task's environmental characteristics, subjects' characteristics and interactions between them. On the other hand, the assessment factors include: cognitive load that can be conceptualized with respect to the dimensions of mental load, mental effort and performance. The mental load in this case refers to load that is imposed by task demands, while mental effort refers to cognitive capacity or resources allocated to accommodate the task demands, and then performance refers to cognitive capacity that is associated to learner's achievements (Paas et al., 2003; Sweller et al., 1998;). Therefore, cognitive load in terms of assessment dimension is either characterized by task-based dimensions (mental load) or learner-based dimensions (mental effort), and the interaction between them. Also, in this case the level of performance achieved is considered as another dimension that reflects all the three causal factors. As identified in the cognitive load theory, Paas et al.(2003) explained task-based dimensions as: the task format, task complexity, use of multimedia, time pressure, and the pace of instruction. The instructional manipulation to change the amount of cognitive load that is experienced by learners will only be effective if they actually invest their mental efforts in the learning activity or task. Thus, Paas and his colleagues argued that two learners can attain the same level of performance or achievement even if they invest different amounts of mental efforts in the learning activity.

The cognitive load was originally categorized into mainly two forms: the intrinsic cognitive load and extraneous cognitive load. While intrinsic cognitive load refers to the intrinsic nature of the material, extraneous cognitive load refers to the learning activities required of students or alternatively, by the manner in which the material is presented (van Merriënboer & Sweller, 2010; Sweller et al., 1998). Then, later on germane cognitive load was introduced as a third category. The germane cognitive load was distinguished from extraneous cognitive load as follows: whereas, extraneous cognitive load reflects the effort required to process poorly designed instruction, on the other hand germane cognitive load refers to mental effort which causes construction of schemas or effort to deal with intrinsic cognitive load and which lead to learning (van Merriënboer & Sweller, 2010; Sweller, 1994; Sweller et al., 1998). Although some researchers had established that it is difficult to distinguish between the forms of cognitive loads, other researchers have attempted to measure the three forms of cognitive load through psychometric rating scale instruments (Leppink et al., 2014). According to Leppink and his colleagues, their first study revealed a three-factor solution for both questionnaires used to measure the cognitive loads, which explained significantly large percentages of total variance for Statistics and Language lessons. Their findings also provided support for recent re-conceptualization of germane cognitive load as the actual working memory resources dedicated to dealing with intrinsic cognitive load.

Cognitive loads can be measured through some specified methods according to researches on instructions and cognition. The literature suggests that it is possible to measure cognitive load by assessing the amount of mental load, mental effort, and performance of the learner (Paas et al., 1994). Then, it was realized that about two methods were introduced in order to measure the amount cognitive load experienced by the learner. These methods include: the analytical method which refers to method that can be used to gather data about mental load, and the empirical methods which were derived in order to measure mental effort and performance through collection of subjective data with rating scales, the performance data with primary or secondary techniques, and psychological data with psychometric instruments (Paas et al., 2003; Xie & Salvendy, 2000). However, researches on the measurement of cognitive loads show that empirical methods have been given more attention than the analytical methods. For example, the use of psychometric rating scales to measure cognitive load assumes that learners can elicit their cognitive processes and report the amount of cognitive load which they experience during a language learning and statistics lectures (Leppink et al., 2014). Therefore, rating scales can provide a practical method to measure the amount of cognitive load that each leaner may encounter during the learning task. This is due to the fact that, although learners may receive same instruction or use same learning materials they can encounter different cognitive load depending on personal ability or due to the nature of learning material or an environment.

3.5.1 Cognitive load theory

The cognitive load theory also establishes important relationship between instructional design and the cognitive load which is experienced by the learners. The basic idea behind cognitive load theory is that; cognitive capacity in working memory is limited to the extent that if a particular learning task requires too much mental load capacity, then the learning will be hindered (Jong, 2010). Due to this problem, instructional designers are advised to select instructional approaches that optimize the use of working memory capacity and avoid overloading the mental capacity

(Chandler & Sweller, 1991). Thus appropriate instructional methods should lower extraneous cognitive load during the learning task and increase germane cognitive load (Sweller et al., 1998). By the way, because cognitive load theory suggests that intrinsic cognitive load is determined by the nature of the learning materials, as well as, the prior learners' knowledge, it may not be directly influenced by instructional design. Also, because extraneous cognitive load reflects the effort that is used to overcome the poorly designed instructions, and that germane cognitive load reflects the cognitive load that contributes to the construction of schemas, then both extraneous and germane can be directly influenced by instructional design (Sweller 1994; Sweller et al., 1998; Paas et al., 2003). Therefore for effective learning outcomes, high germane cognitive load is required because it encourages schema construction, while extraneous cognitive load the less. On the other hand, the three forms of cognitive load are supplementary. That is to say, the total cognitive load must remain the same even if one of the forms is altered during the learning exercise. Thus, instructions should be designed in such a way that they minimize extraneous cognitive load and maximize germane cognitive load irrespective of intrinsic cognitive load which may not be directly influenced by instructional design. Thus, Sweller et al. (1998) argued that if total cognitive load is not exceeded, instructional designs might direct learner's attention to process those instructions that are relevant to learning or construction of schemas, that is to say, increasing germane cognitive load and reducing extraneous cognitive load. The next sub-sections discuss the relationship between cognitive load theory and problem solving instructional approaches as well as example-based learning.

3.5.2 Cognitive load theory in relation to problem solving

As it has been described in the previous section, cognitive load theory play an important role in the design of classroom instructions. Thus, it is important to reconsider the design of problem solving instructional approach with respect to the cognitive load (Sweller et al., 1998). Furthermore, Sweller and his colleagues argued that when an instruction is designed without regarding the capacity or limitations of working memory, because the working memory of human being is limited, and if this limitation is not observed, then learning might be hindered (Jong, 2010; Sweller, 1994). However, so far literatures show that problem solving instructional approach may employ two kinds of problems: the means-end analysis or goal-free problems. Problem solving through means-end analysis (i.e. conventional problem solving) was described as an efficient way to attain solution to a problem without schema construction, imposes heavy extraneous cognitive load, and it is an ineffective approach for schema construction that are associated to learners prior knowledge (Sweller et al., 1998). That is to say, because a conventional problem imposes heavy cognitive load, learners have to consider a number of factors within a given problem. For instance, learners have to associate the current problem state, the problem goal or solution and the difference between the two conditions. Thus, if learners have to solve problems but they are provided with examples, first they are likely to skip examples and deal with actual problem solving and only use the example when they are unable to solve the problem (Van Merrienboer & Paas, 1990; Pirolli & Anderson, 1985). On the other hand, problem solving instructions that involve the goal-free problems in the learning exercise can reduce extraneous cognitive load which is caused by means-end analysis, and so encourage effective learning through schema construction (Sweller et al., 1998). Furthermore, Sweller and his colleagues contended that when solving goal-free problems, learners may find alternative strategy to reach the solutions when compared to means-end analysis problems. For this reason, instructional designers may consider to include goal-free problems in the learning exercise so as to reduce drawbacks that are behind means-end analysis problems. On the other hand, the use of goal-free problems may require more time for learners to solve them, lead into incorrect solutions and misconceptions.

3.5.3 Cognitive load theory in relation to example-based learning

The instructional designs that involve the use of worked-examples or modelling examples when learners have to solve problems have been found to be more effective. As such, problem solving instructions that include the use of examples are said to be more effective than convectional problem solving. The use of worked examples reduces the extraneous cognitive load which is caused by means-end analysis problems, it can enable learners “to generalized solutions or schemas, and focus attention on problem conditions and the associated operators, that is, the current problem state, the problem goal” (Sweller et al., 1998 p.273). For this reason, example-based learning instructional approaches are basically thought of as having more advantages than convectional problem solving approaches especially with means-end analysis. On the other hand, the most important factor may be learner’s ability to acquire knowledge through induced schema and solutions patterns due to reduced extraneous cognitive load.

Also, problem solving instructional strategies that involve the use of worked-examples have some disadvantages. For example, problem solving which involve worked-out examples that are comprised of redundant information may not facilitate effective learning (Paas et al., 1994) because they may not encourage effective schema constructions as much of the mental effort will be addressed on dealing with redundant information, hence increase extraneous cognitive load. Also, if the uses of worked-examples during learning exercise contain high interactivity of elements so that learners require associating them, it may also impose a heavy extraneous cognitive load (Sweller, 1994). Furthermore, according to Sweller et al. (1998), good worked-out examples may be difficult to construct such that overwhelm learning by increasing extraneous cognitive load, and that overuse of worked-examples might limit learners to generate new solutions to problems and hence reduce their learning effectiveness.

The next chapter presents the general research questions guiding the two studies.

CHAPTER FOUR

GENERAL RESEARCH QUESTIONS

The aim of this dissertation is to promote an understanding of how to enhance pre-service teachers' diagnostic competence about identifying pupils' misconceptions in Physics. In the last two decades, the literature indicates that various empirical studies have been conducted in teacher or medical education in order to foster the development of diagnostic competences. These empirical studies have applied experimental research designs and different interventions to enhance diagnostic competences among undergraduate students or inexperienced professionals in both fields. Although, each study focused on enhancing diagnostic competence through an intervention, the studies differ in terms of designs, instructional strategies or learning tasks applied during the learning phase, and other within-study characteristics. As a result, the studies applied different instructional approaches to facilitate the learning process of how to diagnose various aspects. Furthermore, the design features of interventions were also not similar. For instance, some of them involved either two phases: the learning and an assessment phase, or three phases: the learning, practice and assessment phase. The studies measured the learning outcomes (diagnostic competences) objectively although there were some discrepancies in assessment methods. However, one of the open research questions that required scientific answers was about an effect size at which different instructional approaches or learning tasks can enhance diagnostic competences in both fields through an intervention. Therefore, the first general research question in this dissertation was formulated as follows.

General research question 1:

"*To what effect can different instructional approaches foster the development of diagnostic competences through interventions?"*

Another key issue that appears in the literature is the relationship between learners' prior knowledge and the type of instructional approaches applied during the learning phase of an intervention. However, the studies have determined that learner's prior knowledge can hinder or promote the learning of new knowledge depending on whether the prior knowledge is accurate or inaccurate, misleading or not misleading, and whether it relates to the required new knowledge (Thompson and Zamboanga, 2004). In addition, learners with different levels of prior knowledge may benefit differently from a particular type of an instructional approach. For instance, example-based learning instructional approach can best suit learners who have low prior knowledge (van Gog & Rummel, 2010; Renkl, 2014), whereas learners with high prior knowledge can benefit more from problem solving (Kalyuga et al., 2001). On the other hand, in case of learning new or complex skills, researcher has also shown that worked examples can be applied first at initial stages, then as learners gain enough conceptual knowledge, examples should be withdrawn, and let them continue solving problem at their own pace (Kalyuga et al., 2001). In contrast, another perspective arises from other literature and narrates that the prior knowledge may have no impact on the learning outcomes, but rather what learners learn actually depends on individual ability or what is being taught (the content) and how the learning process occurs (Kuhn, 2007).

Moreover, another key issue was about the effect an instructional approach have on enhancing the diagnostic competence in relation to other variables. For instance, the cognitive load encountered during the learning process. According to cognitive load theory, the human mental load capacity is limited and if certain learning activities impose high intrinsic or extraneous cognitive load, then they can reduce mental load capacity allocated to deal with the intrinsic nature of the learning materials or tasks and therefore hinder the learning process (Jong, 2010; Sweller, 1994). Thus, instructional designers need to design learning activities or apply instructional approaches to reduce unnecessary mental load, or enhance the working memory capacity (van Merriënboer & Sweller, 2005; Sweller et al., 1998). Some instructional approaches may influence students' cognitive load during the learning task differently, depending on the presentation mode. For instance, while the use of examples when solving problems can lower students' extraneous load, problem solving applied to structured problems may impose high extraneous load (Sweller et al., 1998). With respect to these perspectives, another open research question about how instructional approaches can influence the development of diagnostic competences with respect to other variable through an intervention is crucial. A second general research question with regard to other factors that can moderate or mediate the effect of instructional approach was also formulated as follows:

General research question 2:

"***How can the effect of instructional approaches on enhancing diagnostic competences be moderated or mediated by other variables?***"

From these two general research questions, the researcher was motivated to conduct a review of the empirical primary studies that are aimed at fostering the development of diagnostic competences through interventions in teacher and medical education in order to summarize their findings. In addition, by conducting a review on the primary studies that focused on enhancing diagnostic competence through interventions, the researcher would learn more about instructional approaches applied during the learning phases. Because most of the studies that focused on fostering the development of diagnostic competences had reported descriptive statistics enough to compute an effect size estimate, then a meta-analysis was deemed necessary in order to synthesize the effect sizes on enhancing the diagnostic competences (Viechtbauer & Cheung, 2010). A meta-analysis would also enable the researcher to compute an estimate of a mean effect size and investigate the influence of moderator variables with respect to this mean effect size.

The next chapter presents a meta-analysis on studies to foster diagnostic competences.

CHAPTER FIVE

FIRST STUDY: FOSTERING THE DEVELOPMENT OF DIAGNOSTIC COMPETENCE THROUGH INTERVENTION: A META-ANALYSIS

5.1 Context of the research problem

Diagnostic competence is important in various fields of study. This is because the information obtained from diagnosis is crucial for making decisions depending on a particular field. In the past two decades, empirical studies that focus on fostering the development of diagnostic competences through interventions in the fields of medical and teacher education have increased in terms of their number and interests. As a result, several empirical studies have been conducted in both fields in order to foster the development of diagnostic competences among undergraduate students or inexperienced professionals. Although these empirical studies are similar in terms of their outcome measures, that is the diagnostic competence, they differ in terms of some specific aspects. For example, the studies differ in terms of experimental designs, methods of facilitating the diagnostic competences, sample characteristics, or the effect sizes on fostering the development of diagnostic competence. In terms of experimental design, while some empirical studies had applied controlled randomized experimental designs (Jarodzka et al. 2012; Mamede et al., 2012; Peixoto et al., 2017), others had employed quasi-experimental designs (e.g. Klug et al., 2016; Liaw et al., 2010; Neistadt & Smith, 1997) in order to foster the development of diagnostic competences through interventions.

With respect to facilitation methods on diagnostic competences, the studies had employed various instructional approaches in order to facilitate the learning process of how to diagnose various aspects among the participants. For example, some studies had applied a problem solving instructional approach (e.g. Bahreini et al., 2013; Ibiapina et al., 2014; Mamede et al., 2014; Peixoto et al., 2017), while other studies had employed example-based learning (e.g. Heitzmann et al. 2015; Jarodzka et al., 2012; Stark et al., 2011) during the learning phase of an intervention to foster the development of diagnostic competence. However, in some cases some primary studies applied more than one instructional approach during the learning phase of an intervention, a situation that was termed as mixture of instructions. Thus, an explicit presentation of information or direct instruction (e.g. lectures) were applied in combination with either problem solving (e.g. Round, 1999) or with example-based learning (e.g. Papa et al., 2007). The direct instruction was used during training in order to facilitate the learning of how to diagnose with much guidance from the instructors (Kirschner et al., 2006), or when large groups of students was available for training, or as less cost effective instructional approach (Cadette et al., 2016; Winarno et al., 2018). Also, in some cases some studies applied a mixture of more than one instructional approach during the learning phase of an intervention. On the other hand, the differences in instructional approaches during the learning phase of an intervention can be linked to heterogeneity of the effect sizes within individual primary studies.

Furthermore, some primary studies applied additional instructional support measures than the given instructional approaches in order to maximize the advancement of diagnostic competence with respect to a particular design of an intervention. For instance, in medical education, structured reflections were used in addition to problem solving (e.g. Ibiapina et al., 2014; Mamede et al., 2012; Mamede et al., 2014) to enhance diagnostic competences. Some other studies applied self-explanation prompts as additional instructional support measures with either example-based learning or problem solving (Chamberland et al. 2011; Heitzmann et al., 2015; Peixoto et al., 2017). Moreover, other studies applied erroneous examples additionally to worked examples or elaborated feedback to enhance diagnostic competences through example-based learning (e.g. Heitzmann et al., 2015; Heitzmann et al., 2018; Stark et al., 2011), or semi-standardized diaries (e.g. Klug et al., 2016) in addition to problem solving and through a well-designed three-dimensional model. However, the findings from primary studies are inconsistent and indicate that in some cases these additional instructional support measures either had supported the development of diagnostic competence among participants, had no effect, or even hindered the advancement of diagnostic competences.

With respect to sample characteristics, participants with different levels of prior knowledge about diagnostic process or the conceptual knowledge, constituted the samples of studies included in the analysis. For example, while in some studies learners with high prior knowledge participated in the interventions (e.g. (Stark et al., 2011), other studies employed learners with low prior knowledge (e.g. Jarodzka et al., 2012). The differences in prior knowledge among different participants in each study could be associated with the effect size on fostering the development of diagnostic competences. The studies have also applied different sample sizes within the individual experimental groups or as a total sample size in a particular study during an intervention to foster the development of diagnostic competences. For instance, some studies (e.g. Liaw et al., 2010) had a small sample size in the experimental group (n = 13) against control group (n = 17), while others (e.g. Round, 1999) applied large sample sizes in an experimental group (n = 84) against control group (n = 102) in order to carry out an intervention.

Nevertheless, the effect sizes of the studies that focused on fostering the development of diagnostic competences in the field of medical or teacher education also varied in terms of magnitude and directions. For example, while some studies reported quite large statistically significant effect sizes (e.g. Mamede et al., 2012), others had reported medium statistically significant effects (e.g. Ibiapina et al., 2014), negative or even null effects on fostering diagnostic competences in terms of strategic or decision-oriented practical knowledge (e.g. Heitzmann et al., 2015; Heitzmann, et al. 2018; Stark et al., 2011). However, all of these differences in effect sizes could have aroused due to different study designs in each primary study or other confounding variables during the interventions. Similarly, the summary of effect sizes could be linked to some other within-study characteristics or features that could moderate the effect of interventions on fostering the development of diagnostic competences in both domains. In terms the of direction of the effects, some studies reported positive effects, or negative effects, or even null effects on fostering diagnostic competences through interventions. We were able to link the differences in effect size directions to the instructional approaches, sample characteristics or their interactions (e.g. prior knowledge versus instructional approaches).

In the light of the reported contradicting findings that might have aroused due to different experimental designs, methods of facilitation, or other within-study characteristics, it was necessary to conduct a meta-analysis in order to synthesize the findings from studies that focused on fostering the development of diagnostic competence through interventions in both fields. A meta-analysis would enable the researcher to compute an estimate of overall or mean effect size, and investigate the influence of some study-level characteristics, or features with respect to the mean effect size estimate. A meta-analysis could also give an insight of the instructional approaches used to facilitate diagnostic competences during the interventions.

5.2 Aim of meta-analysis and specific research questions

The aim of this meta-analysis is to synthesize the findings from empirical primary studies that focus on fostering the development of diagnostic competences of undergraduate students or inexperienced professionals in the field of teacher and medical education in order to understand the overall effect size in enhancing diagnostic competence through interventions. Specifically, this meta-analysis intends to address the following research questions with respect to study characteristics of the primary studies that were included in the sample.

RQ1. To what overall effect can the development of diagnostic competences be fostered through interventions among undergraduate students or inexperienced professionals in teacher and medical education fields*?*

With respect to the first specific research question, it was predicted that the development of diagnostic competences among various participants could be facilitated through different instructional approaches or learning tasks during interventions with a small to moderate overall effect size.

RQ2. What is the moderation effect of the following factors on the development of diagnostic competences through interventions (i) Instructional approach (ii) Prior knowledge (iii) Experimental design (iv) Domain?

Likewise, with respect to the second research question, it was predicted that these within-study level characteristics of the primary studies would moderate the effect of an intervention on enhancing the development of diagnostic competences.

RQ3. How does the moderation effect of the instructional approach during an intervention to foster the development of diagnostic competence vary with the levels of the learners' prior knowledge?

In addition, another prediction made was that there would be significant interaction between the moderation effect of instructional approach and the different levels of participants' prior knowledge or expertise in facilitating diagnostic competences.

5.3 Methods

5.3.1 Literature review search strategies

The literature search was conducted from various databases in order to obtain relevant published and unpublished empirical studies that focused on fostering the development of diagnostic competences through interventions. The databases employed in the searching process included: PsycINFO, PsyINDEX, PsycARTICLES, ERIC and MEDLINE. The following Boolean phrases (diagnost* competenc* OR diagnost* skill* OR diagnost* reason* OR clinic* reason*) AND (train* OR teach*) were used in the search process. As a result, the database search revealed about 2,630 articles after the removal of duplicates. Any relevant study was included in the sample from the databases search until 30th December 2016 although he added some articles obtained through other means until January 2017. Then, the next step was to screen all the studies that appeared to be relevant and conduct a full-text examination afterwards in order to reveal whether a study satisfied the inclusion criteria or not (see section 4.2: for inclusion criteria). Then, one more experienced colleague assessed the relevance of each study independently. We then removed any illegible study from the list so that we could remain with only valid and reliable studies to include in the sample. As a result, we obtained 19 relevant studies through this searching process.

In addition, the current meta-nalysis employed other search strategies to obtain more studies that could be added to the samples. The extra searching of studies included the unpublished manuscripts, dissertations or theses, book chapter and conference proceedings. To do so the researcher wrote e-mails to the first authors of the studies identified through the database search to request any unpublished articles on facilitating diagnostic competences. Moreover, the same process as before was followed to scan these additional reference lists of the articles obtained by the databases search. As a result, we obtained about seventeen published primary empirical studies and one dissertation. After assessing the eligibility of those addition, we obtained three more studies that are relevant. Therefore, 22 studies were included in this meta-analysis.

5.3.2 Inclusion criteria

As the goal of the meta-analysis is to synthesize the findings from a pool of related empirical studies so as to understand the overall effect size and examine the influence of study-level characteristics on the size of the mean effect size (Viechtbauer & Cheung, 2010; Viechtbauer, 2010), the researcher had set some criteria to guide the inclusion process. The studies included in the sample were similar in terms of outcome measures although they applied different methods and interventions to foster the development of diagnostic competences. There were studies that addressed the issue of diagnostic competence but could not fit into the meta-analysis due to some methodological reasons (e.g. research designs). Therefore, to be included in this meta-analysis as a relevant study, the study in question had to meet the following criteria:

(i) A study must be empirical and aims to facilitate diagnostic competences through interventions.

(ii) A study must use an experimental research design with at least one treatment condition.

(iii) The intervention must aim to facilitate diagnostic competence (defined as ability to engage in the goal oriented gathering and integration of information to make medical or educational decisions, COSIMA research group (in press).

(iv) A study must provide statistical data to compute an effect size estimate in terms of standardized mean difference.

5.3.3 Description of the included articles

There were 22 empirical studies included in the sample of this meta-analysis and among this list, there was one unpublished work from a manuscript from a doctorial thesis, and nineteen published articles that comprised of twenty-one empirical studies. Therefore, a sample in this meta-analysis comprised of one unpublished study and twenty-one published studies. An Appendix: A presents a summary of these empirical studies included in the sample, their effect size estimates and their corresponding moderator variables. Moreover, some included studies comprised more than one experimental condition or group as compared to the control condition or group. For instance, there were nine studies (resulting in nine effect size estimates) which comprised a single experimental condition or group when compared to a condition or control group, while 13 studies (resulting into 34 effect size estimates) comprised more than one experimental condition or group when compared to a control condition or group. In general, the researcher computed 43 dependent -effect size estimates because of descriptive statistics and a common control condition or group. In addition, there were 1,954 participants across all studies which comprised a minimum of 30 and maximum of 186 participants. The participants were undergraduate medical students, health practitioners, undergraduate pre-service teachers, or in-service teachers.

5.3.4 Outcome measures

A diagnostic competence was an outcome measure of interest in this meta-analysis. In addition, an outcome measure was supposed to comply with the operational definition of diagnostic competence provided with respect to this meta-analysis. The studies outlined diagnostic competence in different phrases according to the specific objective of the study in teacher education or medical education. In teacher education, the primary studies outlined their outcome measures in terms of accuracy in diagnosing student's learning behaviour (e.g. Klug et al., 2016) or teacher's own teaching actions (e.g. Heitzmann, 2014). On the other hand, in medical education, the included studies outlined their outcome measures in terms of: clinical reasoning, diagnostic knowledge in solving clinical problems, or clinical competences were included in the meta-analysis (Chamberland et al. 2011; Mamede et al., 2014; Neistadt & Smith, 1997; Papa et al., 2007). Moreover, in medicine some studies outlined their outcome measures in terms of accuracy in determining patients illness or diseases (Mamede et al., 2012; Peixoto et al., 2017), or accuracy in determining specific clinical features after a formal training session (Eva et al., 2007). In addition, in medicine diagnostic competences was considered in terms of diagnostic knowledge necessary for gathering information about diagnostic reasoning (e.g. Heitzmann et al., 2015; Stark et al., 2011).

5.3.5 Coding procedures

All the study characteristics were coded by using a pre-defined coding scheme for general features (see Appendix B: Coding scheme of study characteristics/features). The general coding scheme consisted of basic (low-inferences) and complicated (high-inference) study-level characteristics. The following were the basic study-level characteristics: author(s)'s name, year of article or manuscript publication, and total sample size. Others included an experimental research design, participants' characteristics (e.g. domain, year of study, and level of their education). On the other hand, high inferences study-level characteristics comprised of an instructional approach employed in the learning phase of an intervention, participants' prior knowledge or expertise, and descriptive statistics for effect size estimates computation. In addition, some study characteristics were identified as potential moderator variables for the effect of intervention on diagnostic competences. For more details of these moderator variables see Table 4.

The researcher and another trained research assistant coded all the basic study-level characteristics with respect to low-inference categories (e.g. author's name, year of publication, total sample size, experimental design, type of participants, and so on) independently. Then, they discussed the differences in their ratings afterwards to reach an agreement of 100%. In addition, the researcher and another more experienced researcher in the department of psychology coded all high inference study-level characteristics independently. These high inference study-level characteristics were an instructional approach, participants' prior knowledge, and effect size estimates. The interrater reliability for an instructional approach was satisfactory (*Kappa* = 0.73), whereas it was satisfactory too for prior knowledge (*Kappa* = 0.73). The reseacher computed intraclass correlation for the computation of effect size estimates from both ratings and obtained a satisfactory statistic (*ICC* = 0.77). In addition, some other trained research assistants were asked to rate an instructional approach for the presence of problem solving, example-based learning, or direct instruction. The interrater reliability low for problem solving was good (*Kappa* = 0.81), likewise good for example-based learning (*Kappa* = 0.89), and satisfactory for direct instruction (*Kappa* = 0.57). However, any disagreement on the coding of study characteristics or moderator variables was resolved through discussions until we reached a final agreement of 100%.

5.3.6 Moderator variables

Through moderator analysis, we can compare how an overall effect size varies with some potential study-level features or characteristics. In addition, moderator analysis will lead us into an understanding of how we can advance undergraduate students' diagnostic competence through an intervention and so improve their professional training programs. As a result, the following potential categorical moderator variables were identified: (1) instructional approach employed in the learning phase of an intervention. An instructional approach was coded using Dummy variables: either as present or absent with the following sub-categories: (1a) problem solving (present vs. absent), (1b) example-based learning (present vs. absent), or (1c) direct instruction (present vs. absent). Then, as some studies were found to use more than one approach, additional code was created from combination of the above mentioned codes: problem solving/example-based learning/mixture), (2) participants' prior knowledge (low/high), (3) experimental design (randomized/quasi experiment), and (4) domain (medical/teacher education). Table 4 contains some details of these moderator variables, while the description of how to rate each sub-category in each moderator variable follows afterwards.

Table 4: *Moderator variables considered in the meta-analysis*

Moderator	Subcategory	Description
(1) Instructional approach	(1a) Problem solving	Learners practice diagnosis through cases and diagnostic problems.
	(1b) Example-based learning	Learners practice diagnosis through written or modeling examples.
	(1c) Direct instruction	Instructors or computer systems presented the concepts and procedures required for solving diagnostic problems
(2) Prior knowledge		Learners' prior experiences or skills about diagnosis process before they participate in the interventions.
(3) Experimental design		Type of an experiment used in a particular intervention
(4) Domain		Specific field of study or context where an intervention was conducted.

Instructional Approach

An instructional approach moderator variable was first coded as: problem solving (present vs. absent). example-based learning (present vs. absent), or direct instruction (present vs. absent). Then, it was coded as problem solving, example-based learning or mixture because some studies had applied more than one instructional approaches in the learning process of how to diagnose different aspects in the interventions. A problem-solving category comprised primary studies that involved participants in learning tasks, and which required them to solve diagnostic problems with no solutions. The diagnostic problems comprised written cases of students' learning situations or patients' illness or diseases. Indicators for the use of problem-solving strategies comprised key phrases like: solving diagnostic problem cases of student or standardized real or written cases of patients, working on problem cases, or identifying some features of specific items at their own. For example, in the study by Klug et al. (2016), teachers worked on a specific case that was related to one of their own students whom they had chosen. Similarly, medical students used a set of written clinical cases to practice diagnosis in the study in which the effects of reflection on cases was compared to generating a single or differential diagnosis (Mamede et al., 2014).

On the other hand, examples-based learning category comprised primary studies that presented learners with written or modelling or examples on how to solve diagnostic problems. In some cases, some studies illustrated how to carryout diagnosis through videos according to a particular learning context. Some key words provided clue to the use of example-based learning instructional approach. These words include phrases like participants practiced diagnosis through worked-out examples or modelling examples, a software provided an illustration of how to diagnose, or the use of erroneous examples. For example, modelling examples were used to teach clinical reasoning skills based on visual observations of patients symptoms among medical students (e.g. Jarodzka et al., 2012). Furthermore, Heitzmann et al. (2018) applied example-based learning in their study whereby student teachers studied two text-based worked-examples in which a fictitious student teacher prepared and implemented lessons following the instructional approach problem-based learning.

The learning tasks with direct instruction involved instructors or computer systems that present the concepts and procedures required to solve a diagnostic problem. The following key words/phrases gave clues for the use of direct instruction: use of lectures to train participants about a particular topic or concept, direct teaching of a lesson, or presentation of written learning materials. For instance, in the study to examine the effect of a classroom-as-clinic format (Neistadt & Smith, 1997), medical students attended lectures weekly throughout a semester under two course and lab instructors. However, some studies applied a direct instruction in combination with either problem-solving or example-based learning instructional approaches. For instance, undergraduate medical students were taught according to well designed protocol based on a clinical scenario or problem-based learning approach (e.g. Round, 1999), while in another learning situation students interacted with computer-based tutor with examples of case to represent problem's disease (e.g. Papa et al., 2007). Additionally in some situations, the studies applied problem solving in combination with example-based learning. Therefore, a mixture of categories of an instructional approach was coded if a study applied more than one instructional approach during the learning phase of an intervention.

Prior knowledge

We coded moderator variable prior knowledge as either high or low, depending on the learners' experiences that they disposed of before participating in the intervention. While several studies directly stated that participants were either familiar or unfamiliar with the topic, or had little or high experience with the diagnosis encountered during the learning phase, in some cases authors did not directly describe participants' prior experience or their experiences. In this case, we used the information about learners' general levels of education (e.g. year of the study) to rate a particular level of participants' prior knowledge. For example, a study by Liaw et al. (2010) did not explicitly refer to learners' prior knowledge but they mentioned that participants were in first year of bachelor of nursing degree program.

Experimental design and domain

The experimental design moderator variable was coded as either 'Yes' or 'No' depending on whether the participants were randomly assigned in different conditions or groups (randomized experiment) or not (quasi-experiment). For this possible moderator variable, most of the primary studies included in the sample had clearly stated whether participants were randomly assigned in a particular experiment or not. Thus, the coding procedure for this moderator variable was straightforward. Then, we also coded a moderator variable domain as either 'medical education' or 'teacher education' depending on the type of participants and learning environment of a particular intervention. For instance, interventional studies which aimed to enhance medical students' (e.g. Baghdady et al., 2014) or health practitioners' diagnostic competences (Bahreini et al., 2013; Liaw et al., 2010) were coded as medical education, while those that focused on teachers' or pre-service teachers (e.g. Heitzmann et al., 2018; Klug et al., 2016) were coded as teacher education.

5.3.7 Statistical analysis

Computation of the effect size estimates

In this meta-analysis, all the effect size estimates were computed in terms of standardized mean difference (Cohen's *d*). The standardized mean differences have been chosen because the primary studies included in the sample had applied different methods and scales of measurements, although on the same outcome measures of interest (Borenstein et al., 2009; Schwarzer et al., 2015). Then, the descriptive statistics for experimental conditions or groups (e.g. means, standard deviations) were applied to compute an effect size estimate of the individual study in comparison to a common control condition or group. However, if a particular primary study did not report one of the descriptive statistics enough to compute the effect size estimates, they were requested from the first authors of the studies (articles) through emails. In addition, an online calculator as given by Lenhard and Lenhard (2016) was applied to simplify the calculations of the effect size estimates.

Finally, the resulting effect sizes (Cohen's *d*) were converted into Hedge's (*g*), which is an unbiased estimate of effect size. The formula (4.23) as given in Borenstein et al. (2009) was used for converting these effect sizes. Moreover, some studies had several dependent outcome measures that addressed the same outcome measure (diagnostic competence). That is, authors of the primary studies had provided multiple descriptive statistics (mean scores and standard deviations) for each experimental condition or group as compared to a common control condition or group. In this case, the researcher computed an average of mean scores and standard deviations for each experimental condition or group (i.e. mean of means) and their corresponding standard deviations (i.e. mean of standard deviations) and obtained a single outcome measure for the main data analysis as proposed by Borenstein et al. (2009). However, most of the primary studies contained more than one treatment conditions or groups, and thus the researcher assumed dependent multiple effect size estimates per study.

Data analysis procedures

To analyze the data, the researcher applied a random effect model (REM). This is because the study-characteristics and outcome measures varied substantially between the studies that a common effect size for all studies could not be assumed (Borenstein et al., 2009). Also, because different research design and samples characteristics might introduce heterogeneity in the true effect size estimates, a random effect model could best suit the main data analysis (Viechtbauer & Cheung, 2010). Moreover, under REM, there are several options for estimating some useful statistics. For instance, the between studies variance (*Tau-squared*) and other percentage of variability (*I-squared*) which both describe the heterogeneity in effect sizes (Quintana, 2015; Schwarzer et al., 2015). Then, the researcher applied a robust variance estimation (RVE) method to analyze data with R-packages (*R version 3.2.2*) so that it could handle the dependent effect sizes from studies that comprised of more than one dependent effect sizes in the same analysis (Fisher & Tipton, 2015; Hedges et al., 2010).

In addition, the researcher applied a mixed-effects model to test for moderation effects of instructional approach following a stepwise procedure. In the first step, he entered each sub-category of the instructional approach moderator: problem solving, example-based learning and direct instruction into a meta-regression models separately so that he could observe the evidence for moderation effect of presence or absence of each factor without accounting for the influence of another moderator. Then in the next step, he entered each of these moderators into a meta-regression model in combination with prior knowledge to determine their interaction effects.

The researcher also applied meta-regressions with either hierarchical or correlated effects. The 'hierarchical effects' was applied in the meta-regression models for the moderator analysis, while a 'correlated effects' was applied in the meta-regression models in order to compute the mean effect size. The hierarchical effects were accounted for because participants in primary study (level-1), provided effect size estimates in multiple studies (level-2), which were nested within larger group of studies, for instance a cluster of studies that applied problem solving instructional approach, (level-3) (Tanner-Smith et al., 2016; Tanner-Smith & Tipton, 2014).

5.3.8 Test of publication bias and influential cases

A publication bias in this meta-analysis was tested through funnel plot and Egger's regression. It was necessary to assess for publication bias because usually, studies which report statistically significant results are likely to be published (Borenstein et al., 2009; Quintana, 2015). A funnel plot can be used to visualize potential publication bias in meta-analyses although some other means are available for this test, for instance Egger's regression test (Egger et al., 1997; Quintana, 2015; Borenstein et al., 2009). A funnel plot is a statistical graphical tool to assess the publication bias by plotting effect sizes and their corresponding standard errors on a two-dimensional figure. If the funnel plot is skewed, there is a publication bias, and condensations can be found. According to Egger et al. (1997), assessing the presence of publication bias using funnel plots bears certain risks because the ability to detect biases might be limited when a meta-analysis is based on a small number of studies. Thus, Egger's test (which also has the advantage that its interpretation is objective) was also applied for this test in order to test for presence of publication bias through R through prior installation of 'metafor' and 'robumeta' packages which is an open-source software for analyzing data in meta-analysis (Polanin et al., 2017).

However, we can use some methods to test for influential cases or studies in the sample that provide extreme effect sizes. A function which is available in the R-metaphor packages for influential cases identification was applied for this although some other methods may be used e.g. case deletion (Viechtbauer, 2010). To test for the studies which would qualify as influential cases and/or as outliers in the main results, the following diagnostics measures were applied in the meta-regression models: externally standardized residues (rstudent), DFFTIS value, Cook's values, and Covariance ratios. Moreover, the researcher applied some other tools from diagnostics features as illustrated by Viechtbauer (e.g. the estimate of Tau-squred or statistical residues for heterogeneity when a study is removed form the analysis).

5.4 Results

5.4.1 Publication bias and influential studies

The Funnel plot and Egger's regression test revealed no indication of publication bias. Most of the effect sizes are distributed equally on both sides of a vertical line for summary of effect size estimates across all studies in a Funnel plot (see in Figure 1). Moreover, the Funnel plot shows that the majority of effect sizes are in the middle and near the bottom of the funnel, while only a few are at the top (i.e. studies with smaller standard errors) to be an outlier.

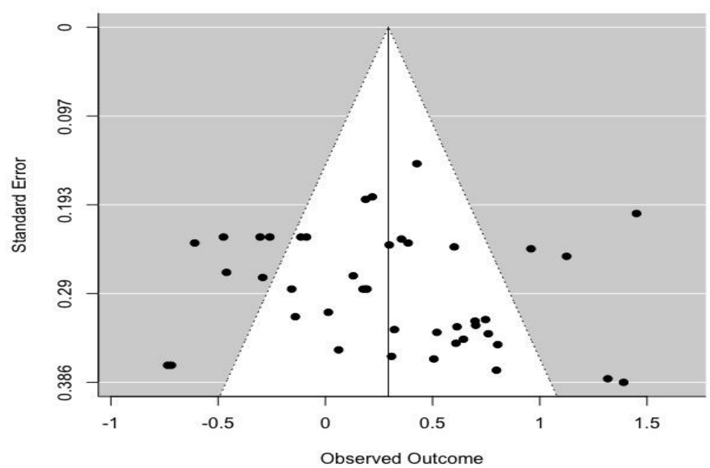


Figure 1. Funnel plot for studies included in the meta-analysis

The Egger's regression test (p = .26) for funnel plot asymmetry was not statistically significant which indicate the absence of publication bias. The results also suggest that one study by Papa et al. (2007) seems to have more influence on summary effect size than other studies. The outputs from externally standardized residues, DFFITS values, Cook's distance, and Covariance ratios also suggest that this study had an influence to the main results (see Appendix C). Additionally, the outputs from Tau-squared deleted effect and statistical residue for heterogeneity suggest that this study would qualify as influential in this meta-analysis. Excluding a study by Papa and his colleagues in the main analysis, the value of Tau-squared estimate does not change significantly which indicates that the study introduces little residue heterogeneity into the model. However, the summary of effect size and moderator analyses show that the direction and magnitudes of the mean effect size as well as the significance of the model do not change significantly. The study seems to have modest influence if we remove it from the analysis and therefore it was retained in the analysis although it seems to be an outlier.

5.4.2 Effect at which diagnostic competences can be fostered through interventions (RQ1)

A meta-regression analysis with robust variance estimation was used to estimate the mean effect size across all studies included in the sample and compute the overall mean effect size at which the development of diagnostic competences can be fostered through interventions (*RQ1*). Figure 2 displays a forest plot that shows the studies included in the sample and their corresponding effect sizes. The size of the squares shows a study weight, while a rectangular polygon at the bottom of the plot represents mean effect size across all studies. The results obtained show a statistically significant medium mean effect size across all studies ($g = 0.37$, $p < .01$; 95% CI = [0.15, 0.6]) according to Cohen (1988). The summary of effect size in this meta-analysis is according to small sample correction (*Rho* = 0.8). In addition, the sensitivity analyses showed consistency of results for the mean effect size estimate ($g = 0.37$, $SE = 0.11$, *Tau sq*. = 0.22) across all values of sample size corrections (i.e. *Rho* = 0 to 1). The results also show that the percentage of variability (I^2) across studies was 76.8%, the value that indicates high relatively observed variation that could be addressed to the actual difference in effect sizes among the studies that were included in the meta-analysis. Furthermore, the results have also revealed a significantly larger than zero total amount of heterogeneity (*Tau-sq*. = 0.22) between the true effect sizes. On the other hand, this amount of heterogeneity was large enough to conduct the moderator analysis in order to find out the sources of the differences in true effect sizes.

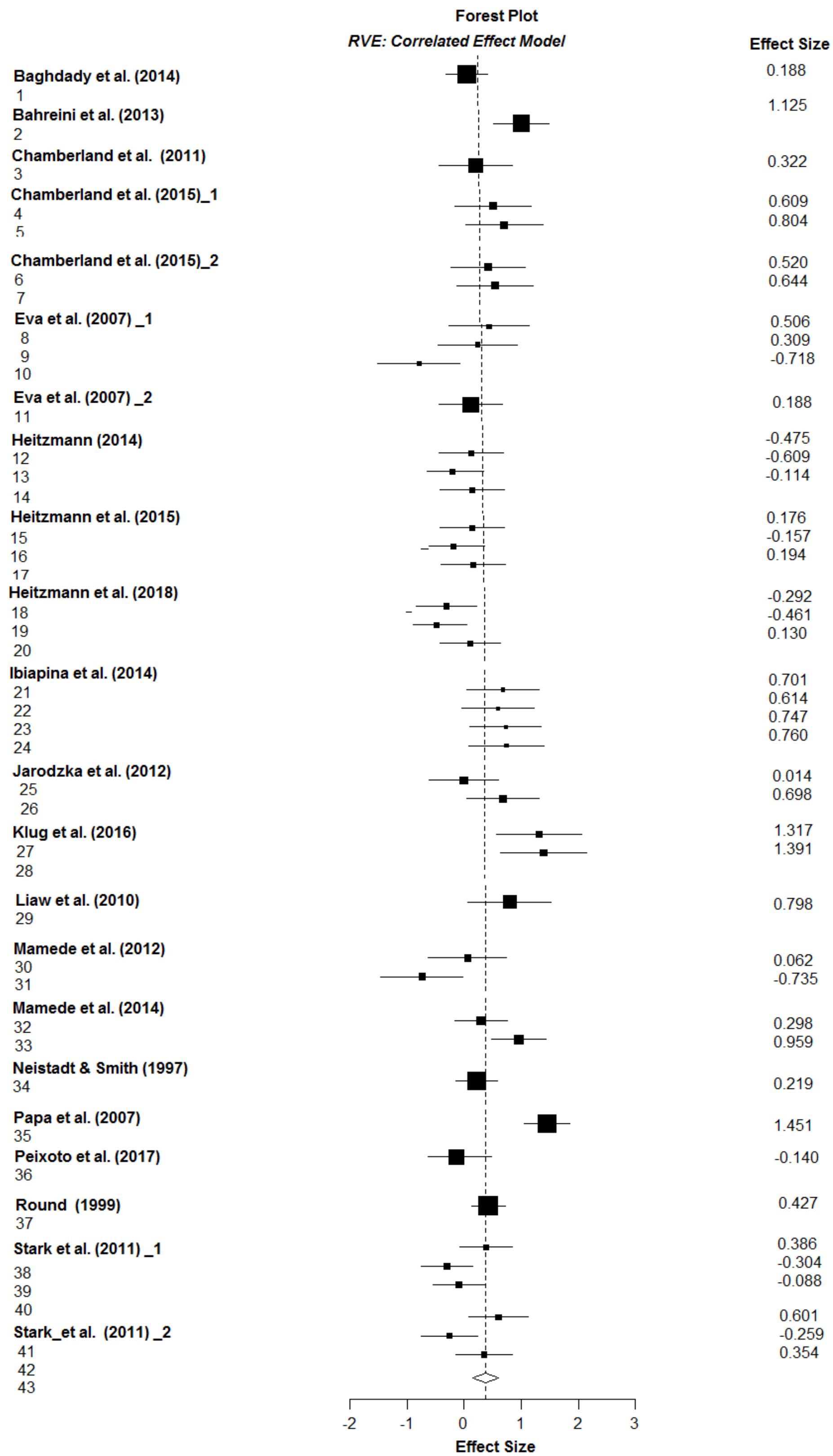


Figure 2. Forest plot of studies included in this meta-analysis

5.4.3 Moderation effect of instructional approach, prior knowledge, and other factors (RQ2)

The meta-regression analyses using robust variation estimation method were conducted in order to find out the effects of potential moderators: instructional approach, prior knowledge, experimental design, and domain on the advancement of diagnostic competences through interventional learning tasks (*RQ2*). The significance of moderators, mean effect size estimates for clusters of studies in each category, standard errors, corresponding 95% Confidence Intervals, and other important statistical parameters for potential moderators are displayed into Table 5. The results obtained show that an instructional approach was a significant moderator ($p < .05$) when problem solving instructional approach were present in the learning process of how to diagnose various aspects in medical and teacher education. The mean effect size of cluster of studies that employed problem solving during the learning tasks reached statistical significance ($g = 0.49$, $p < .001$). The results obtained further show that cluster of studies that employed example-based learning instructional approach was small and did not reach statistical significance. In contrast, studies that did not employ example-based learning appeared to be significant (p < .05), while the mean effect size of cluster of these studies was high and reached statistical significance ($g = 0.51$, $p < .05$). On the other hand, an instructional approach appeared not to be a significant moderator when alternatively categorized as: problem solving, example-based learning or mixture. However, the mean effect size of cluster of studies that applied mixture of instructional approaches ($g = 0.43$, $p < .05$) was statistically significant. The observed mean effect size of studies that employed only problem solving instructional approach ($g = 0.46$, $p = .093$) was larger than that for a cluster of studies that employed either only example-based learning instruction or a mixture of approaches during the learning tasks of how to diagnose although it did not reach statistical significance.

Moreover, the moderator analyses indicate that a group of studies that participants had low prior knowledge was significant ($p < .01$), while those studies with high prior knowledge participants was not. The mean effect size of studies with low prior knowledge learners was larger than those with high prior knowledge and reached statistical significance ($g = 0.46$, $p < .001$). Likewise, a group of studies that applied quasi-experimental studies seems to be a significant moderator ($p < .05$) although it had less power to account for the results. The mean effect size for this group of studies was larger than that of studies that applied randomized experiments, and again it reached statistical significance. The medical domain also seems to be a significant moderator ($p < .05$) with significant mean effect size although it was less than that of teacher education domain. Moreover, the values of within-cluster between-study variance component (*Omega-squared*) and between-cluster variance components (*Tau-squared*) for all moderators were greater than zero. The values of between-cluster variance components also show that the true effect sizes of studies that fall under these categories were heterogeneous; a construct which is necessary for moderator analysis. These parameters represent the inverse variance weights for hierarchical and correlated effects, and are available as default options in the R packages (Tanner-Smith et al., 2016).

Table 5: *Summary of results for moderator analysis from RVE meta-regression models on the development of diagnostic competences through interventions (n = 43, k = 22)*

Moderator	**Category**	**Sig. of moderator**	***ES(g)***	***P***	***95 % CI***	***SE***	***df***	***n(k)***	ω^2	τ^2
Instructional approach										
	Problem solving (NO)	.59	0.08	.590	[-0.25, 0.40]	0.135	6.13	19(8)	0.09	0.09
	Problem solving (YES)	< .05	0.49	.003**	[0.21, 0.76]	0.124	10.51	24(14)		
	Example-based learning (NO)	< .05	0.51	.015*	[0.13, 0.88]	0.159	7.06	16(10)	0.10	0.10
	Example-based learning (YES)	.11	0.17	.195	[-0.10, 0.44]	0.121	9.32	27(12)		
	Direct instruction (NO)	.06	0.27	.055	[-0.01, 0.55]	0.126	10.58	30(14)	0.04	0.18
	Direct instruction (YES)	.78	0.35	.196	[-0.24, 0.94]	0.238	5.73	13(8)		
	Problem solving	.11	0.46	.093	[-0.13, 1.04]	0.203	3.69	11(6)	0.03	0.15
	Example-based learning	.90	0.02	.899	[-0.35, 0.38]	0.128	3.83	14(5)		
	Mixture	.10	0.43	.048*	[0.004, 0.85]	0.185	8.44	18(11)		
Prior knowledge										
	Low	< .01	0.46	.009**	[0.15, 0.77]	0.133	7.93	16(9)	0.05	0.15
	High	.19	0.20	.173	[-0.11, 0.51]	0.139	10.07	27(13)		
Experimental design	Quasi	< .05	0.81	.032*	[0.12, 1.50]	0.244	3.79	6(5)	0.09	0.11
	Randomized	.07	0.21	.080	[-0.03, 0.45]	0.110	13.35	37(17)		
Domain										
	Medical	<.05	0.29	.015*	[0.07, 0.51]	0.105	15.2	38(20)	0.04	0.18
	Teacher education	.96	0.34	.731	[-9.12, 9.79]	0.744	1.00	5(2)		

Note: n = number of effect sizes, k =number of studies, Sig. = Significance, *ES* = mean effect size of cluster of studies, g = Hedge's g, *SE* = standard error of the mean effect size, ω^2 (*Omega sq*.) = within-cluster between-study variance component, τ^2 (*Tau sq*.) = between-cluster variance component. ** $p < .01$, * $p < .05$

5.4.4 Moderation effect of interaction between instructional approach and prior knowledge (RQ3)

A mixed effect meta-regression with RVE method was also conducted in order to test for moderation effect of interaction between instructional approach and participants' prior knowledge on the development of diagnostic competences through intervention (*RQ4*). The mean effect sizes for the interaction between instructional approach and levels of prior knowledge for each cluster of studies, significance for each interaction, and other parameters are displayed in Table 6. The results obtained from meta-regressions models show that the interaction between instructional approach (problem solving) and prior knowledge (high) was statistically significant (p < .05) although its mean effect size did not reach statistical significance. Likewise, an interaction between an instructional approach (example-based learning) and prior knowledge (high) on the development of diagnostic competence was statistically significant (p < .05) although the mean effect size for this interaction was small and negative. The interaction between example-based learning instructional approach and low prior knowledge appeared to be a significant moderator (p < .01) even though it had low degree of freedom. Also, if example-based learning instructional approach was applied for learners with low prior knowledge, it had a medium positive mean effect on the development of diagnostic competences through interventional learning tasks (g = 0.35, p < .001). The results obtained further show a statistically significant mean effect of an interaction between instructional approach mixture and low prior knowledge (g = 0.49, p < .05), although it did not reach statistical significance.

Table 6: *Moderation effect of interaction between instructional approach and the levels of prior knowledge from RVE meta-regressions (n = 43, k = 22).*

Interaction of moderator variable	Sig. of moderators interactions	*ES (g)*	*P*	*95 % CI*	*SE*	*df*	ω^2	τ^2
Instructional approach*prior knowledge								
Example-based learning*prior knowledge (low)	< .01	0.35	.006**	[0.31, 0.39]	0.003	1.00	0.18	0.05
Mixture*prior knowledge (low)	.47	0.49	.044*	[0.02, 0.98]	0.188	5.13		
Problem solving*prior knowledge (low)	.94	0.39	.491	[-4.40, 5.18]	0.377	1.00		
Example-based learning*prior knowledge (high)	.83	-0.03	.833	[-0.47, 0.40]	0.137	2.99	0.00	0.18
Mixture*prior knowledge (high)	.44	0.32	.487	[-1.09, 1.73]	0.398	2.53		
Problem solving*prior knowledge (high)	.11	0.48	.125	[-0.22, 1.18]	0.241	3.58		
Presence of instructional approach*prior knowledge								
Direct instruction (YES)*prior knowledge (low)	.65	0.36	.336	[-0.73, 1.46]	0.307	2.5	0.25	0.00
Example-based learning (YES)*prior knowledge (low)	.59	0.51	.032	[0.07, 0.95]	0.175	5.24	0.12	0.08
Problem solving (YES)*prior knowledge (low)	.61	0.4	.036	[0.04, 0.77]	0.143	5.13	0.23	0
Direct instruction (YES)*prior knowledge (high)	.71	0.33	.488	[-1.13, 1.79]	0.41	2.51	0.00	0.22
Example-based learning (YES)*prior knowledge (high)	< .05	-0.07	.582	[-0.38, 0.25]	0.112	3.98	0.00	0.11
Problem solving (YES)*prior knowledge (high)	< .05	0.56	.092	[-0.18, 1.86]	0.186	6.48	0.00	0.12

Note. Sig. = Significance, *SE* = standard error of the mean effect size, *ES* = mean effect size of cluster of studies, *g* = Hedge's g, ω^2 (*Omega sq*.) = within-cluster between-study variance component, τ^2 (*Tau sq*.) = between-cluster variance component, ** $p < .01$, * $p < .05$.

5.5 Discussion

The findings from this meta-analysis indicate that we can foster the development of diagnostic competences through interventions and a moderate effect size. On the other hand, the size of the mean effect size might have depended on the effect sizes across the individual studies, which in turn depends on a number of further factors. For instance, the extent to which studies manipulated the independent variable in order to see the effect on the dependent variable or the settings of the experimental conditions compared to the control condition. Furthermore, the findings obtained have reveal a high percentage of variability and a larger than zero amount of heterogeneity across the studies included in the sample. The high percentage of variability indicates that there was a sufficiently observed proportion of variation in the effect size between the studies, while a large amount of heterogeneity in effect size between the studies indicates that the studies that were included in the sample did not share a true common effect size. That is, the studies included in the sample had examined a heterogeneity of effect sizes and hence the researcher could reject the null hypothesis that these studies had investigated similar effects (Borenstein et al., 2009). In addition, a large amount of heterogeneity in effects between the studies encouraged the researcher to conduct a moderator analysis in order to find out the sources of these differences in effect sizes between the studies (Quintana, 2015).

The findings from the moderator analysis suggest that an instructional approach is a significant moderator variable, if problem solving was used during the learning process. However, when an instructional approach was categorized as: example-based learning, problem solving or mixture; instructional approach as a moderator appeared not to be significant. In general, these findings imply that diagnostic competences among undergraduate students can be improved through learning tasks that involve problem-solving instructional strategies than example-based learning or direct instruction. Moreover, the use of diagnostic cases when practicing diagnosis may modulate the learning of how to diagnose various aspects in both fields. For instance, some primary studies (Klug et al., 2016; Mamede et al., 2012) which were included in the sample of the meta-analysis indicated that learners who were provided with cases and practiced diagnosis through problem solving led to largely observed positive effect sizes. A large positive effect on enhancing diagnostic competences in these studies may also be probably due to the additional instructional support (e.g. structured reflections, standardized diaries), provided to facilitate the learning process. On the other hand, an instructional approach seems to be a promising moderator if a mixture of more than one approach is applied in the learning process although it did not reach statistical significance. Thus according to the findings from this meta-analysis, the use of more than one instructional approach seems to be an effective instructional approach during the learning process of how to diagnose various aspects in both fields. However, some researchers have criticised the traditional way of applying both instructional approaches (i.e. problem solving and example-based learning), (e.g. Renkl et al., 2000). They argued that, the traditional way of combining problem solving and example-based learning is static and may not support transition from learning through examples in initial stages of the knowledge development to later stages of problem solving. According to Renkl and colleagues, the fading procedure, that is, providing learners with complete examples first, then applying more incomplete examples, and finally letting them solve problems on their own, can foster the acquisition of new knowledge and skills especially for near learning transfer performance.

In addition, the findings obtained have indicate that prior knowledge is a significant moderator variable if participants who have low prior knowledge are involved in the learning task of how to diagnose various aspects in both fields. This finding implies that even learners with low prior knowledge can learn effectively with problem solving instructional approaches, although the theory points out to the fact that they could have learned better with example-based learning (Renkl et al., 2000; Renkl, 2014; Tuovinen & Sweller, 1999). Furthermore, the findings indicate that employing a quasi experimental research design was a significant moderator. It appears that non-randomly assigning participants could have led into better outcome measures with problem solving than randomly assigning participants into different groups. However, the research methodology suggests that randomly assigning participants to different groups during an experiment allows for better control of other random factors/confounding variables, for instance, personal ability (Creswell, 2012). The findings have also indicated that the medical education domain is a significant moderator variable and imply that studies conducted in the medical education field could have enhanced diagnostic competences among the participants better than the studies conducted in teacher education.

Another important finding in this meta-analysis was about the moderation effect of the interaction between the instructional approaches and the levels of learner's prior knowledge. That is to say, the moderation effect of an interaction between problem solving, example-based learning or direct instruction approaches and the learners' prior knowledge. The findings show that the moderation effect of the interaction between problem solving and high prior knowledge is a significant moderator. However, the interaction effect between the presence of example-based learning instructional approach and low prior knowledge seems to be a significant moderator although the degree of freedom for this interaction effect was too low (df = 1.00). These findings are in line with the theoretical perspectives which suggest that learners with high prior knowledge would learn better with problem solving instructional approaches, than those with low prior knowledge with example-based learning (Kalyuga et al., 2001; Kalyuga, 2007). According to Kalyuga and his colleagues, learners who have low prior knowledge may benefit more from instructional approaches that provide more guidance (e.g. example-based learning), while instructional approaches that encompass less guidance (e.g. problems solving) can best suit learners who have high prior knowledge. Thus, according to literature, the effectiveness of the instructional approaches that were employed in the learning phases of the studies included in this meta-analysis can be linked to the levels of learners' prior knowledge (Kalyuga et al., 2001).

The moderation effect of the interaction between example-based learning instructional approach and high prior knowledge appears to be a significant moderator variable, although it yields a small negative effect size (g = -0.07). Again, these results seem to be in line with the findings on the “expertise-reversal effect” which explained that instructional approaches that best suit learners of low prior knowledge (e.g. example-based learning) can have no impact and even can have negative effects when used with learners of high prior knowledge (Kalyuga et al., 2003). However, the findings from other researches on the effectiveness of example based learning (van Gog & Rummel, 2010; Renkl, 2014; Renkl et al., 1998) suggest that learners with low prior knowledge may benefit more from example-based instructional approaches especially at the acquisition of new skills. Thus, the finding from this meta-analysis seem to support the past research findings which show that learners with low prior knowledge might learn best through example-based learning, whereas, those with high prior knowledge can learn the best with problem solving instructional approaches.

The findings in this meta-analysis have implications for both theory and practice. Concidering research theory, the findings firstly imply that instructional approaches that involve solving problem and the use of diagnostic problem cases during the learning phase of an intervention can be more effective on enhancing diagnostic competences than those that employed direct instruction or example-based learning. Secondly, learners’ prior diagnostic knowledge seems to be a covariate to the effect of instructional approach on enhancing diagnostic competences through interventions especially when learners with low prior knowledge are involved in the learning tasks. Thirdly, the type of experimental design seems to be a factor when enhancing diagnostic competences through interventions. This is because the difference between random assigning of participants and non-random assigning of them to different treatment conditions during an intervention is a significant moderator. Fourthly, the context where diagnosis takes is also a factor since the difference between diagnosing in medical education and in teacher education is a significant moderator.

As for practice, the findings in this meta-analysis support the fact that learning tasks that involve solving diagnostic problem cases during the learning phase of an intervention, can facilitate the development of diagnostic competences better than employing either example-based learning or direct instruction. Furthermore, in practice the finding imply that instructional strategies that have been used to foster the development of diagnostic competences in medical education can be applied to enhance teachers’ diagnostic competences especially when we apply cases of students having particular learning difficulties.

However, the findings from this meta-analysis might be limited due to some factors. For instance, the fewer number of studies included in the meta-analysis when compared to the standard one (at least 40), might have affected the results especially when estimating meta-regression coefficients with the robust variance estimation (*RVE*) method (Tanner-Smith & Tipton, 2014). With a few number of studies (less than 40), RVE tends to produce narrow confidence intervals especially when estimating meta-regression coefficients, and less than 3 degree of freedoms which can lead to less reliable results. In order to overcome the problem, the data analysis applied a small sample correction (*Rho* = 0.8) into the meta-regression models during data analysis, although some degrees of freedom for some moderator analyses (e.g. the interaction effects) were still less than the required value.

In conclusion, the current meta-analysis has revealed that we can facilitate the development of diagnostic competences among undergraduate students or inexperienced professionals in the fields of teacher education or medical education through interventions with a medium positive effect size. An instructional approach is a significant moderator if we apply problem-solving in the process of how to diagnose various aspects both in medical and teacher education. Some other factors: learner's prior diagnostic knowledge, experimental design, and domain or context are potential moderator variables when enhancing diagnostic competence among undergraduate students or inexperienced professional. This meta-analysis also seems to justify the reconceptualization that example-based learning instructional approaches can best fit learners with low prior knowledge, whereas, problem solving may best fit learners of higher prior knowledge.

The next chapter presents an empirical study to investigate the effects of two instructional approaches on enhancing diagnostic competence.

CHAPTER SIX

SECOND STUDY: ENHANCING PRE-SERVICE TEACHERS' DIAGNOSTIC COMPETENCE IN PHYSICS MISCONCEPTIONS THROUGH PROBLEM-SOLVING AND EXAMPLE-BASED LEARNING

6.1 Context of the research problem

As part of formative assessment practices, diagnostic competence is crucial for science teachers and can play a big role in the teaching and learning process. This is because science teachers must obtain information about students' conceptual understanding of science ideas, their possible misconceptions, and then improve the learning process of science (Chin, 2001; Morrison & Lederman, 2003; Treagust, 1988). Thus, science teachers need to continuously diagnose learning situations in classrooms to obtain the necessary information that would help them to reflect on and evaluate their teaching practices, regulate their own teaching approaches, or facilitate the conceptual change among the students (Busch et al., 2015; Hoth et al., 2016; Morrison & Lederman, 2003; Seo et al., 2017; Smolleck & Hershberger, 2011). However, one of the challenges in teaching and learning process of physical sciences (e.g. Physics) especially at middle or high schools is pupils' held misconceptions that can arise due to various factors. For instance, common misconceptions in Physics may occur due to pupils' beliefs, how they observe physical phenomena in everyday life, or the way they generalize their observations differently from the well-known scientific ideas or concepts (Chin 2001; Shipstone, 1984). In addition, misconceptions in Physics can also arise due to the following classroom interaction patterns: a student interacting with another student, a student interacting with the learning resources, or the interaction between a student and a teacher (e.g. if she or he receives incorrect classroom instructions). According to the literature, misconceptions in physical sciences can be resistant to change if classroom teachers do not detect and correct them during the learning process (Gurbuz, 2015; Smith et al., 1994). That is, if classroom teachers do not identify students' misconceptions during the teaching and learning process, they can hinder the learning of new Physics ideas, or get carried over. Therefore, it is necessary for Physics teachers at middle or high schools to identify and correct pupils' misconceptions before they become resistant to the learning process.

On the other hand, to identify pupils' misconceptions in Physics effectively, teachers need to develop diagnostic competences as early as possible especially during initial professional training programs (Busch et al., 2015; Klug et al., 2013; Smolleck & Hershberger, 2011). This is because at this stage of professional training, it is crucial for prospective teachers to begin developing this competence for identifying pupil's misconceptions in Physics. Also, once this competence is developed right from begining of professional training, teachers can apply it later for effective formative assements. However, an issue remains regarding how we can improve pre-service teachers' diagnostic competence through potential instructional approaches during initial professional training programs. According to the empirical studies in the meta-analysis (the first study in the current research), some instructional approaches were employed during the learning phases as interventions, in order to foster the development of diagnostic competences among undergraduate students or inexperienced professionals in teacher or medical education fields. For example, some studies applied a problem solving instructional approach during the learning phase of the intervention. These interventions usually applied diagnostic cases of students' having learning difficulties or cases of patients with some diseases among undergraduate students of teacher or medical education (Chamberland et al., 2011; Chamberland et al., 2015; Eva et al., 2007; Klug et al., 2016; Schmidt et al., 1996). Undergraduate students in both domains usually learn how to diagnose cases where a student is having learning difficulties in teacher education, or cases of a patient's diseases in medical education. Thus, with problem solving, professional undergraduate students would learn how to solve diagnostic problems using previous knowledge, or knowledge which they gain during the training phase (Heitzmann et al., 2018; van Merriënboer, 2013; Stark et al., 2011). Moreover, some studies that focused on enhancing diagnostic competence through interventions in both fields have indicated that written problem cases have been mostly applied in the learning phase as learning materials on how to diagnose various situations of interest (Ibiapina et al., 2014; Klug et al., 2016; Mamede et al., 2012).

The empirical studies of the meta-analysis (first study) also applied example-based learning as instructional approach to foster the development of diagnostic competences through interventions with positive effects in teacher education as well as in medical education (e.g. Chamberland et al., 2015; Eva et al., 2007; Heitzmann et al., 2018). In the example-based learning instructional approach, undergraduate students applied examples of how to make a diagnosis with various techniques. For example, by providing learners with examples of an expert solving a problem, or seeing video clips that demonstrate how a particular diagnostic problem can be solved through examples, or by having learners study worked examples (van Gog & Rummel, 2010). Another possible technique under the example-based learning instructional approach is to provide learners with worked examples integrated with errors. For example, pre-service teachers were trained how to diagnose classroom situations through example-based learning and text-based worked examples with errors in a computer learning environment (Heitzmann et al., 2018). According to Heitzmann and her colleagues, the error explanation prompts had a positive effect on declarative-conceptual knowledge if combined with adaptable feedback, while it had hindered practical diagnostic knowledge. However, although the primary studies applied other instructional approaches (e.g. direct instruction) during a learning phase of an intervention, in most cases they applied problem solving and example-based learning, reporting effect sizes that hinder proper interpretation of which one of them would support the development of diagnostic competences more effectively.

The findings from the meta-analysis in this dissertation has revealed that diagnostic competences among undergraduates or inexperienced professionals can be facilitated with a medium effect size and that it might be facilitated the best way through a problem solving instructional approach. According to this study, the use of problem solving seems to be more effective than example-based learning probably because complex learning goals in own experiences with diagnostic problems are necessary for the learners (Kalyuga et al., 2001). Also, the problem solving approach seems to be more effective than example-based learning on fostering the development of diagnostic competences especially with learners who have high prioir knowledge (Kalyuga & Sweller, 2004). However, the primary studies in the meta-analysis also indicate that example-based leaning approaches have also been applied to foster the development of diagnostic competences with some significant effects especially by applying additional instructional approaches (Chamberland et al., 2015; Heitzmann et al., 2015; Peixoto et al., 2017; Stark, et al., 2011). On the other hand, the literature also indicates that example-based learning might be the best instructional approach for learners with low prior knowledge (van Gog & Rummel, 2010; Tuovinen & Sweller, 1999), and that it can be suitable for the acquisition of new skills (Renkl, 2014). Thus, for pre-service teachers, one can predict that example-based learning might facilitate the learning of how to diagnose pupils' misconceptions in Physics better than problem solving. However, for pre-service teachers at undergraduate level, an open question remains about the effect at which we can apply these instructional approaches to enhance diagnostic competence in identifying pupils' misconceptions in Physics.

Another important issue to investigate in this study is about the influence of other variables that can moderate or mediate the effect of the instructional approach on enhancing pre-service teachers' diagnostic competences. For instance, the cognitive load that pre-service teachers may encounter during the learning process might be one of these variables (Heitzmann et al., 2018; Kalyuga & Singh, 2016). Thus, during the learning process learners can encounter challenges with regard to cognitive load due to unnecessary mental load (intrinsic cognitive load) from the learning tasks, or due to extraneous mental effort to cope with the demands of tasks or the manner in which the learning materials are presented, (extraneous load), or the mental capacity devoted to dealing with intrinsic nature of the learning materials (germane load) and leads into learner's performance (Paas et al., 2003; Sweller et al., 1998; van Merriënboer & Sweller, 2010). The learning materials or tasks that involve high interactivity can also impose a heavy intrinsic load, while those instructional approaches that are properly designed can impose heavy extraneous cognitive load that can affect the learning of how to diagnose various aspects (Sweller, 1994; van Merriënboer & Sweller, 2010). On the other hand, the cognitive load theory describes the limitation of human working memory, and we should consider this limitationn when selecting an instructional approach to effectively facilitate the learning process (Chandler & Sweller, 1991; van Merriënboer & Sweller, 2005; Sweller et al., 1998). According to cognitive load theory, instructional designers need to construct effective instructional approaches to minimize the extraneous cognitive load, and maximize the germane cognitive load. This is because an instructional approach can directly affect the extraneous cognitive load, than intrinsic load or the nature of the learning materials to intrinsic cognitive load as well as germane cognitive load (van Merriënboer & Sweller, 2010).

According to Sweller et al. (1998), problem-solving approaches may apply either means-end analysis or goal-free problems. Although problem solving through means-end analysis (i.e. conventional problem solving) is an efficient way to attain solution to a problem without schema construction, it can impose a heavy extraneous cognitive load (Sweller et al., 1998). On the other hand, according to Sweller and his colleagues, problem-solving instructions that involve goal-free problems in the learning task can reduce extraneous cognitive load that is caused by means-end analysis, and thus increase germane cognitive load that might cause effective learning due to schema construction, an organized and stored unit of pieces of information in the long-term memory. Thus, if goal-free problems are included in the learning task, they can reduce drawbacks due to means-end analysis problems. However, the use of goal-free problems is difficult to attain, it may require much time for learners in solving problems, and if not well handled, it can lead to incorrect solutions or even misconceptions. Unlike problem solving, if worked examples (example of solutions) are incorporated in the learning task, they can reduce the extraneous cognitive load which is caused by means-end analysis problems, enable learners to generalize solutions, and focus attention on the current problem state and the goals (Sweller et al., 1998). Also, solving problems through worked examples that have redundant information may neither facilitate effective learning nor encourage schema construction because much of the mental effort will be used to deal with unnecessary information, and hence increase extraneous cognitive load (Paas et al., 1994). Moreover, if worked examples are used during learning task that contains high interactivity of elements that require learners to associate them simultaneously, it may also impose a heavy extraneous cognitive load (Chandler & Sweller, 1991; 1994). Therefore, the issue remains at which effect both problem solving and example-based learning instructional approaches can influence cognitive load, and whether cognitive load can mediate the effect of an instructional approach on enhancing pre-service teachers' diagnostic competence. The following study was designed to address these research questions through an intervention. The sample included undergraduate students of a Bachelor of Education with Science (pre-service teachers) from one of the University College of Education.

6.2 Aim of the study and specific research questions

The aim of this study is to investigate the effect of an instructional approach on enhancing pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics through an intervention in order to improve the teacher-training program at undergraduate level. In addition, this study intends to address the general research questions about the effects of the instructional approaches on fostering the development of diagnostic competences through an intervention and the effect of other variables. To do so, the researcher designed an intervention and applied the two prominent instructional approaches in order to enhance pre-service Physics teachers' diagnostic competences through an intervention. Specifically, the study intends to examine the effect of problem solving and example-based learning on enhancing pre-service teachers' diagnostic competences through an intervention. Therefore, with respect to the general research question and the purpose of the study, the researcher derived the first specific research question and its underlying predictions as follows:

RQ 1: ***To what effect can problem-solving and example-based learning instructional approaches enhance pre-service teachers' diagnostic competence in identifying pupil's misconceptions in Physics*?**

Although the primary studies in the meta-analysis applied both instructional approaches to enhance diagnostic competences on various specific aspects, contradicting findings still existed. However, in order to diagnose pupils' Physics misconceptions we needed to get more information about the effects of the two instructional approaches on enhancing pre-service teachers diagnostic competences. According to the purpose of the study, a researcher chose the learning materials from two specific topics in Physics. In addition, in order to compare the effect of each instructional approach fairly through an intervention, a similar condition was maintained for both experimental groups except for the manipulation of the approaches as independent variables. The literature has indicated that both instructional approaches have been used to foster diagnostic competences of undergraduate students (e.g. student teachers) in various aspects with some significant effects at varying degrees. Therefore, the researcher expected that both instructional approaches would significantly enhance pre-service teachers' diagnostic commence, but with different effect sizes. It was also necessary to find out which of the two instructional approaches could effectively enhance pre-service teachers' diagnostic competence. Therefore, a second specific research question and the underlying predictions is also derived with respect to the general research questions as follows:

RQ 2*: How does problem solving instructional approach differ from example-based learning on enhancing pre-service teachers' diagnostic competence in identifying Physics misconceptions*?

The literature indicates that example-based learning instructional approaches are an effective means of learning complex skills, or can suit learners with low prior knowledge especially during early stages (for example at undergraduate level) of skill development better (Renkl et al., 2000; Renkl, 2014; Tuovinen & Sweller, 1999). Because diagnostic competence in identifying pupils' misconceptions might also be a new professional skill that requires Physics pre-service teachers to develope it through training intervention, the researcher expected that example-based learning would enhance pre-service teachers' diagnostic competences more effectively than problem solving.

Furthermore, the researcher expected that the instructional approaches would influence pre-service teachers' cognitive loads during the learning task of how to diagnose pupils' misconceptions in Physics due to design features of the learning materials or tasks, or the manner in which instructional approaches presented learning tasks in each experimental condition (Sweller, 1994; van Merriënboer & Sweller, 2010). However, an instructional approach (a predictor) can influence both a cognitive load (a process variable) and the diagnostic competence (an outcome variable) during the learning process. Then, it was necessary to investigate the correlation between pre-service teachers' diagnostic competence in the form of conceptual and procedural knowledge and cognitive load that pre-service teachers might encounter during the learning process. This would also give us more information about the relationship between cognitive load and diagnostic competence. Therefore, the researcher derived two more specific research questions with respect to correlation between cognitive load and the diagnostic competence, and the effect of an instructional approaches on cognitive loads:

RQ 3: *What is the correlation between pre-service Physics teachers' diagnostic competence and cognitive load encountered during the intervention*?

RQ 4: *To what effect does the problem-solving or the example-based learning instructional approaches influence pre-service Physics teachers' cognitive load during an intervention*?

As previously mentioned, the extent to which learners invest mental effort in order to understand the particular learning materials differs due to some factors. According to Sweller (1994), intrinsic cognitive load is directly influenced by the intrinsic nature of the learning tasks or materials, than extraneous cognitive load, by the instructional approach. Likewise, some researchers have indicated that learning materials which involve high interactivity of elements can impose heavy intrinsic cognitive load too, and if they are inappropriately presented, they can also cause heavy extraneous cognitive load (van Merriënboer & Sweller, 2010). Then, if we minimize both intrinsic and extraneous cognitive loads, the remaining memory resources will be allocated to deal with intrinsic load and hence we will maximize the germane cognitive load, and implicitly,we may enhance effective learning as a result of this productive allocation of mental effort (Paas et al., 2003). However, pre-service teachers would encounter different amounts of cognitive load during an intervention due to an influence of the instructional approaches.

Therefore, the researcher derived another specific research question to address this causal relationship as follows:

RQ 5: ***At what extent can cognitive load mediate the effect of problem solving or example-based learning on enhancing pre-service teachers' diagnostic competence*?**

According to the literature, the researcher anticipated that a cognitive load would significantly mediate the effects of the instructional approaches on enhancing pre-service teachers' diagnostic competences during an intervention. Furthermore, a mediation effect was considered here rather than a moderation effect because the effect of instructional approaches on diagnostic competences would be explained through cognitive load as a process variable rather than a combined effect (Field, 2013). That is, the researcher could explain the relationship between the instructional approaches (predictor) and the diagnostic competence (outcome) through cognitive load as a third variable. Also, because an instructional approach could also predict a cognitive load that might correlate with diagnostic competence (outcome measure), the mediation effect was an appropriate analysis to explain this causal relationship.

On the other hand, there have been arguments whether we can really measure and distinguish the three types of cognitive loads. Thus, a research question about whether the newly developed psychometric instrument could differentiate beteween the three types of cognitive load during an intervention was also crucial in this study. That is, whether an adopted subjective rating scale could measure and distinguish between the three types of cognitive load during an intervention to enhance pre-service teachers' diagnostic competence through problem solving and example-based learning. In addition, the literatures show that it is possible to measure cognitive load by assessing learners mental load, mental effort, or performance through some empirical methods (Paas et al., 1994). Thus, just a few years ago some researchers have attempted to measure and distinguish between the three types of cognitive load (Leppink et al., 2014). According to Leppink and colleagues, their findings have revealed a three-factor solution for a language and statistics lecture. The current research aimed at finding out whether the same questionnaire can measure three types of cognitive load in the intervention to enhance pre-service teachers' diagnostic competence. Thus, another specific research question that addressed these issues was formulated:

RQ 6*: To what extent can the adopted questionnaire differentiate between the three types of cognitive load during the intervention to enhance pre-service teachers' diagnostic competence*?

Although, some previous research findings on learning and cognition show that it is difficult to clearly distinguish between the types of cognitive loads (e.g. Jong, 2010; Kalyuga, 2011), Leppink et al. (2014) attempted to measure the three forms of cognitive load by using a developed psychometric instrument to elicit learners mental loads. According to findings from Leppink and his colleagues, the researcher also predicted that this questionnaire could measure and distinguish the three types of cognitive load during the intervention.

Conceptual framework guiding the study

The following conceptual framework guided the study (see Figure 3). It analyzed in details the relationship between a predictor (independent variable) and an outcome measure (dependent variable). The predicting factors in this case were problem solving and example-based learning instructional approaches, while the outcome measures was diagnostic competence in form of declarative-conceptual and procedural knowledge. According to Field (2013), the effect of the instructional approaches on enhancing pre-service teachers' diagnostic competences could be predicted through a cognitive load (another variable) in which learners could encounter during an intervention. However, the instructional approaches could also influence a cognitive load due to some factors: the design features of learning materials, instructional approaches, or mental effort allocated to deal with the intrinsic nature of the learning tasks and which can lead to actual learning (van Merriënboer & Sweller, 2010; Sweller, 1994; Sweller et al.,1998). Therefore, one of the predictions was such that pre-service Physics teachers would encounter cognitive load due to design features of the learning materials or instructional procedures employed in the learning phase of an intervention. Then, another prediction was that there would be an indirect effect of instructional approach on enhancing pre-service teachers' diagnostic competence through the cognitive load as a mediator. Moreover, another prediction was made that there would be a correlation between pre-service teachers' diagnostic competences and the cognitive loads encountered during an intervention since both can be influenced by the learning tasks or an instructional approach. Finally, another prediction was that the learning tasks or instructional approaches would cause learners to encounter different amounts of cognitive load during an intervention.

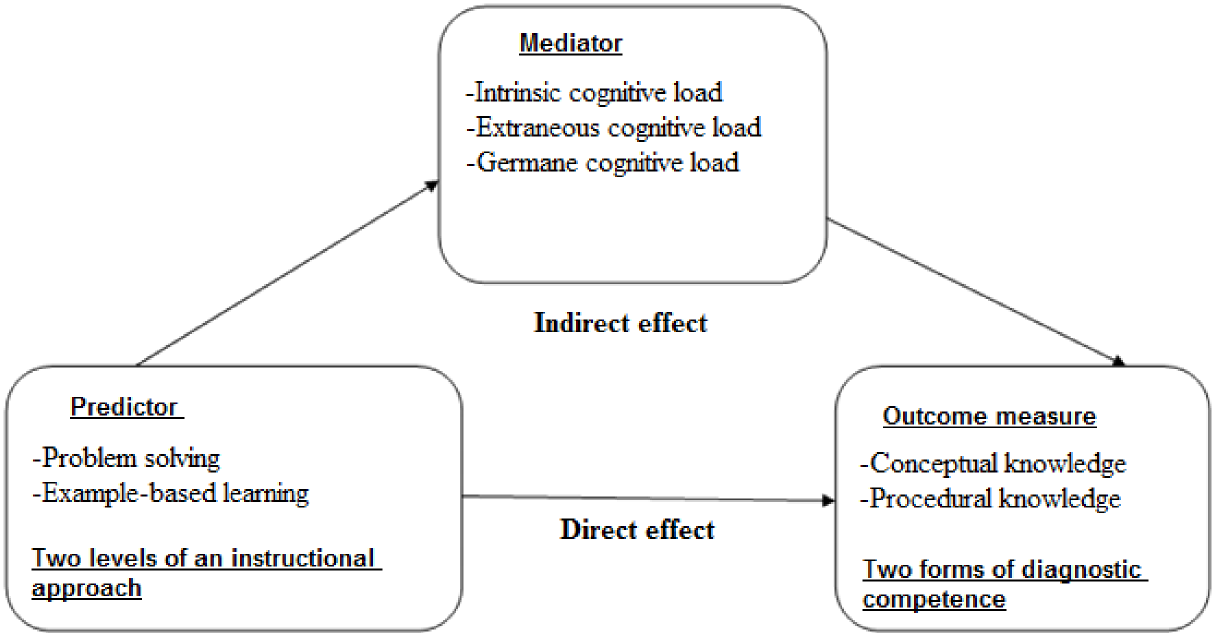


Figure 3. Conceptual frame work guiding the study.

Source: Adapted from Field (2013)

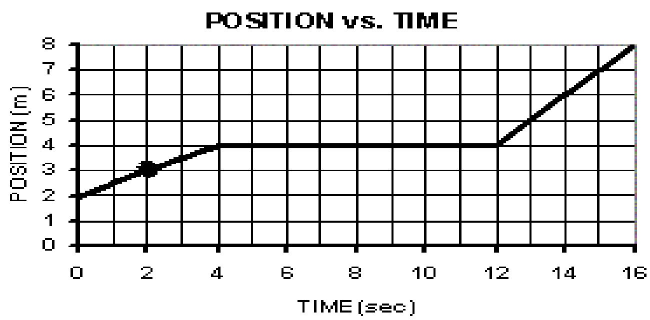
6.3 Methods

6.3.1 Sample size and design

The sample size for this study comprised of 81 undergraduate students (pre-service teachers) of Bachelor of Science (with education) program. These pre-service teachers were perusing Physics as one of their major subject. On average, the pre-service teachers were 25.09 years old (*SD* = 2.04) and with min age of 22 and max age of 35 years. Among them, 86.4% were male pre-service teachers, while 13.6% were female. The sample was drawn from one of the constituency University College of Education of the University of Dar Es Salaam in Tanzania. All pre-service teachers participated in the intervention voluntarily after asking their informed consents. The researcher offered some refreshments and reimbursed them equally with little money to cover their travelling costs and the meals. The study applied a between-group experimental research design with pre and post testing of the dependent variable. The pre-service teachers were randomly assigned to two experimental groups and one control group whereby, pre-service teachers in a control group did not practice in the training about diagnosing pupil's misconceptions in Physics, but participated in both pre and post testing phases of an experiment as well as the measurements of cognitive load. The pre-service teachers' pre test-scores were applied as covariate in this study.

6.3.2 Learning environment

The learning materials in this study consisted of models of a 'Diagnoser tool' prepared through imaging, a situation whereby a fictitious pupil was interacting with a computer program that produces questions and answers via the internet. The questions intended to elicit different facets of pupil's conception of ideas or misconceptions in Physics Mechanics and Electricity. A facet is defined as a framework for organizing the research on student conceptions of ideas in a manner that both discipline experts and teachers will understand it (FACET Innovations, LLC organization, 2008). These frameworks include facet clusters with specific learning objectives arranged for different subtopics (see Table 2 in chapter two). Moreover, if an imaginary pupil completes responding to a set of questions or problems, a teacher could view conceptions of ideas (facets) diagnosed for each question. Figure 4 displays the sample of a question selected from Physics Mechanics at middle or high schools according to FACET Innovations, LLC organization (2008). Table 2 (in chapter two) also summarized the details of each facet. However, the facets that begin with the small numbers (e.g. 2X) to large ones (e.g. 9X) indicate ideas that have more problematic aspects. That is, the higher the facet numbers, the more problematic the ideas. According to FACET Innovations, the X0's facets indicate more general statements of student ideas or objectives and are often followed by more specific examples, which are coded as X1 to X9.



How far has the object traveled from the beginning of the motion (t=0s) to the point indicated by the dot on the graph (t=2s)?

[a] ○ 0 meters

[b] ○ 0.5 meters

[c] ○ 1 meter

[d] ○ 1.5 meters

[e] ◉ 3 meters

Key	Facet number
A	80
B	72
C	02
D	Unknown
E	42

Figure 4: Sample of a question selected from Physics Mechanics (position and distance)
(Source: http://www.diagnoser.com)

First experimental condition:

The training materials in the first experimental condition were prepared in order to implement the problem solving instructional approach using models of a Diagnoser tool. The models comprised of prompts of a fictitious pupil's answers as he or she interacts and responds to a particular Physics question or problem case via the internet. A dot or blue highlight indicated the prompts of pupil's answers to these questions (see Figure.5). Then, pre-service Physics teachers had to practice diagnosing pupil's misconceptions by using a set of guiding questions but without solutions or answers. The pre-service teachers were granted practicing diagnosis with discussions in small groups. In addition, a trainer gave feedback at the end of each session whenever necessary in order to clarify unclear diagnosis. Optionally, the researcher provided pre-service

Physics teachers with printed sets of facet lists in this experimental condition so that they could view possible pupil's conception of ideas with respect to these problem cases. The guiding questions for this model of a 'Diagnoser tool' were intended to guide the learning process among pre-service teachers who were supposed to practice diagnosing pupil's misconceptions in Physics through solving problems. Figure 5 displays a sample of diagnostic problem case that applied in the problem-solving experimental condition.

Question or problem case:

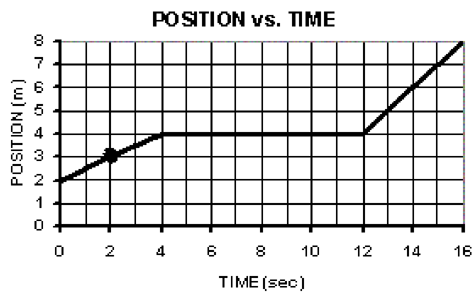


Figure one

The motion of an object during a 16-second time period is graphed as shown in figure one above.
What is the object's position at the point indicated by a dot on the graph? **Note**: *A pupil's answer is given by a dot or highlight.*

- (•) 0.5 meters
- ( ) 1 meter
- ( ) 2 meters
- ( ) 3 meters

Guiding questions:

i. *How do you judge about the pupil's answer in this question?*
ii. *If it is wrong which one do you think is the correct answer*?
iii. *State how a pupil has decided to choose an answer in this question?*
iv. *Identify and write down a particular misconception held by a pupil in case there is false conception of ideas.*
v. *Identify any other possible misconception held by a pupil who selects another alternative response in this que*
(see ***alternative responses****).*

Figure 5: Sample of diagnostic problem case used in experimental condition one
(Source: http://www.diagnoser.com)

Second experimental condition:

The learning materials in the second experimental condition applied similar problem cases as those in first experimental condition, but they were embedded with examples of misconceptions for each particular wrong conception of an idea to implement an example-based learning instructional approach. A pre-service Physics teacher in the second experimental condition was supposed to practice how to diagnose pupil's misconceptions through set of examples of misconceptions illustrating the diagnosis for a particular problem case. In addition, pre-service Physics teachers in this experimental condition were asked to provide reasons as for why a fictitious pupil might have a particular misconception. This is because the models of examples of misconceptions already provided solutions to the questions when practicing diagnosis. Figure 6 displays a sample of a question or problem case used in the second experimental condition.

Question or problem case:

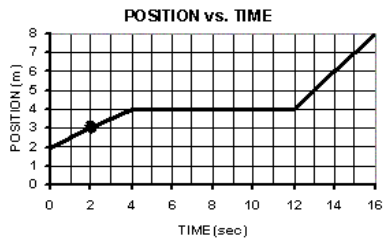


Figure one

The motion of an object during a 16-second time period is graphed as shown in figure one above.
What is the object's position at the point indicated by a dot on the graph? **Note**: *A pupil's answer is given by a dot or highlight*

- [a] 0.5 meters
- [b] 1 meter
- [c] 2 meters
- [d] 3 meters

Model of solutions

Key	**Conception of idea**	**Misconception**	**Reason behind**
a	Wrong	Pupil does not distinguish position from speed	
b	Wrong	Pupil does not distinguish between position and distance	
c	Unknown	-	-
d	Correct	-	-

Figure 6: Sample of diagnostic problem case used in experimental condition two.
(Source: http://www.diagnoser.com)

Diagnoser tools:

Therefore, two types of models of 'Diagnoser tool' for implementing either problem solving or example-based learning instructional approach were applied during the learning phase of an intervention. A set of Diagnoser tools consisted of 15 questions or diagnostic problem cases each of which comprised of nine cases from Mechanics and six cases from Electricity. The appendices D and C contain a full set of these training materials. The researcher under the guidance of his with the supervisors carefully prepared these training materials for the intervention. The colleagues in the Departments of Educational Psychology and Physics of the University of Munich in Germany revised the materials before fieldwork. In addition, the researcher piloted the training materials at another constituency of University College of Education of the University of Dar Es Salaam in Tanzania before intervention. This university college had similar characteristics and learning environment like the one in which the intervention was conducted.

6.3.3 Procedures

The training on how to diagnose pupils' misconceptions in Physics was conducted through a one-day training workshop, and it consisted of an intervention with two training sessions and a break in between them. The first training session took 2 h and 30 min, while the second one took 2 h. The training on how to diagnose pupils' Physics misconceptions in Mechanics was conducted during the first session, while the training on diagnosing misconceptions in Electricity was conducted in the second session. Participants were randomly assigned into three groups using small cards numbered 1, 2 and 3. The researcher identified group one and two as experimental groups and the third group as control group, but participants did not know this information. However, the trainers had participated in the pilot study; therefore, they might have an idea about the grouping but not the details of the experiment. The trainers were assistant lecturers in the Department of Physics from another constituency University College of Education of the University of Dar Es salaam. These two university colleges have the same characteristics in terms of curriculum, teaching staff, and undergraduate programs. All pre-service Physics teachers answered a questionnaires intended to assess their prior diagnostic knowledge before the intervention. The pre-testing took one hour.

Learning phase

The pre-service teachers in the first experimental condition practiced how to diagnose pupils' misconceptions in Physics by using a model of 'Diagnoser tools' for implementing problem solving as instructional approach. The pre-service teachers practiced diagnosis through proble-solving by using seveal guiding questions without solutions or answers. In this experimental condition, the researcher provided pre-service Physics teachers with printed sets of facet lists so that they could view details of pupils' facets elicited from the learning materials whenever necessary. Pre-service Physics teachers discussed any unclear diagnosis situations in small groups of three to five. A trainer in the experimental condition gave feedback at the end of each session whenever necessary in order to clarify any unclear diagnosis. During the second training session (after lunch break), the trainers interchanged between the experimental conditions in order to reduce any instructional factor that could arise due to personal ability. In the second experimental condition, pre-service teachers practiced how to diagnose pupils' misconception in Physics by using models of 'Diagnoser tools' with similar problem cases, but rather embedded with modelling examples of solutions with particular misconceptions. Additionally, in this experimental condition, pre-service teachers explained a reason behind any of the fictitious pupil's misconceptions provided. A trainer did not give any feedback in this experimental condition, while pre-service teachers were also allowed to discuss in small groups. The researcher conducted the interventions for both experimental conditions simultaneously. The control group did not practice diagnosis but rather participated in other procedures of an intervention (e.g. pre-test, cognitive load measurements) similarly to experimental groups. All pre-service teachers answered a second questionnaire for the measurement of cognitive load twice, (i.e. once at the end of each training session).

Testing phase

After the second training session was finished, all participants answered a questionnaire to measure the cognitive load for the second time. Then, they got an offer of refreshments. The researcher then conducted a post testing whereby participants in the two experimental groups answered the same questionnaire (i.e. knowledge test) used in the pre-testing to measure their diagnostic competence (conceptual and procedural knowledge) after an intervention. The pre-service teacher in control group also participated in post testing at this stage. Finally, the researcher met participants in the control group for some minutes to brief them about the training materials and promised to provide them with the same practice by the following weekend.

6.3.4 Data sources and instrumentation

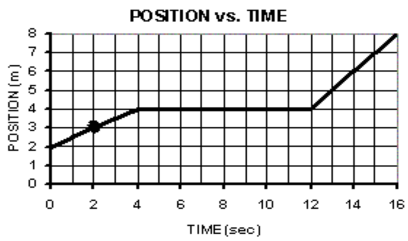
Pre-testing data:

A multiple choice knowledge test was used to measure pre-service teachers' prior diagnostic knowledge before intervention. The test consisted of two sections: first section for measuring declarative-conceptual knowledge, and a second section for measuring procedural knowledge. A section to measure declarative-conceptual knowledge consisted of 32 multiple-choice items with four alternatives each. These items were derived from different questions but similar to problem cases that were used in the training phase. An item of the first section of this knowledge test was scored with either one point or zero, depending on whether a pre-service teacher selected a correct or wrong answer respectively. Figure 7 shows a sample of an item in the first section of the diagnostic knowledge test. A section to measure pre-service teachers' procedural diagnostic knowledge consisted of three questions with four to six alternative items. Appendix E presents a full set of test items for both sections of this knowledge test. During scale formation, nine items in (10, 14, 18, 23, 24, 25, 26, 30 and 31) were removed from the first section of the diagnostic knowledge test (conceptual knowledge) in order to increase its internal consistency. The criteria used were, if an item is deleted its Cronbach's alpha would be higher than the overall Cronbach's alpha for all items retained in the test. The reason was to increase reliability of the test. For example, for conceptual knowledge, when these nine items were removed the Cronbach's alpha was raised from $\alpha = 0.66$ (all items in the pre-testing) to $\alpha = 0.71$. However, in the scale formation for procedural knowledge, all items were retained because removing any one of them could not increase Cronbach's alpha for the items. Table 8 presents a summary of Cronbach's alpha for conceptual and procedural knowledge during the pre-testing.

Process data:

The process data were obtained by measuring the cognitive load that pre-service teachers could encounter during the learning phase of an intervention. A subjective rating scale questionnaire (Likert scale) measured a cognitive load during the learning phase.

Pupil's question:



Figure

The motion of an object during a 16-second time period is graphed as shown in the figure above.
How far did the object travel in the 16 seconds? **Note:** Pupil's answer (*in dark dot or blue highlight*):

- 6 meters
- 8 meters
- 10 meters
- 16 meters

Example of a multiple-choice item:

Qn. What is the pupil's misconception in this problem?
(a) The pupil incorrectly identifies initial position as zero
(b) The pupil incorrectly identifies final position as 8 meters
(c) The pupil incorrectly identifies initial position as 2 meters
(d) No any misconception in this question [ ]

Figure 7. Sample of an item used for measuring conceptual knowledge.
(Source: http://www.diagnoser.com)

The rating scale consisted of 10 points and it was adopted from a researchers' study (Leppink et al., 2014). The questionnaire comprised 13 items: four items intended to measure intrinsic cognitive load, four items for measuring extraneous cognitive load, and five items for measuring germane cognitive load. The scale ranged from zero ("*Not at all*") to ten ("*Completely the case*"). Appendix F displays the whole questionnaire for the measurement of cognitive loads. Then, because the cognitive load was measured twice: in the middle of an intervention and by the end, then a total score for each type of cognitive load (intrinsic, extraneous, and germane) per participant was computed by taking the mean of each item from the first and second measures of a particular type of cognitive load. Table 7 shows an example of computation procedures for overall scores for intrinsic cognitive load. During scale formation, all items are retained in this instrument because removing any one could improve its reliability. Table 8 presents Cronbach's alpha for overall cognitive load.

Table 7: *Sample of computation procedures for overall cognitive lead.*

Type of cognitive load	First measure	Score	Second measure	Score	Average score
Intrinsic CL	intr_1_1	8	intr_1_2	1	4.5
	intr_2_1	4	intr_2_2	2	3
	intr_3_1	2	intr_3_2	3	2.5
	intr_4_1	7	intr_4_2	4	5.5
Total					15.5

Note. CL = Cognitive load, intr = intrinsic

Post-testing data: The same multiple-choice knowledge test measured pre-service teachers' diagnostic knowledge after an intervention. Likewise, during the scale formation we removed nine items to increase consistency of the test. Cronbach's alpha was raised from α = 0.72 (all items) to α = 0.80. Again, all items were retained during the scale formation for procedural knowledge because removing any one of them could not increase Cronbach's alpha. Table 8 presents a summary of Cronbach's alpha for conceptual and procedural knowledge during the post-testing.

Table 8: *Summary of internal consistency of instruments during intervention.*

Measure	Cronbach's, α
Pre-testing	
conceptual diagnostic knowledge	0.71
procedural diagnostic knowledge	0.67
Process	
Overall intrinsic cognitive load	0.74
Overall extraneous cognitive load	0.69
Overall germane cognitive load	0.91
Post-testing	
conceptual diagnostic knowledge	0.80
procedural diagnostic knowledge	0.68

6.3.5 Statistical analysis

The following statistical tests were applied to analyze data in this study: multivariate analysis of variance (MANOVA) and multivariate analysis of covariance (MANCOVA). However, also some other statistical procedures were applied to analyze the data in this study. These included the following: the bivariate correlation with Pearson correlation coefficients, mediation analysis through Hayes's PROCESS tool, and an explanatory factor analysis (FA). The Discriminant analysis was also used to follow up MANOVA with three grouping variables. A MANOVA test was used to test the effect of instructional approach (independent variable) on diagnostic competence in terms of conceptual and procedural knowledge as dependent variables (RQ1). Alternatively, a MANCOVA statistical test was used to test the effect of instructional approach (independent variable) on diagnostic competence when a covariate (prior diagnostic knowledge) was included in the model. Moreover, these multivariate tests were also used to test for the effect of instructional approach on the cognitive load (RQ4). The researcher applied simple standard and the planned contrasts for group comparisons (RQ2) to test the hypothesis that instructional approaches would enhance pre-service teachers diagnostic competence above the level seen in the control group. A mediation analysis was applied in order to determine the effect of instructional method (a predictor) on the pre-service teachers' diagnostic competence (outcome variable) through cognitive load as process variable (mediator) which was encountered during an intervention (RQ5). Additionally, the bivariate correlation was used to compute correlation between cognitive load and diagnostic competence in form of conceptual and procedural knowledge (RQ3). Then, explanatory FA was conducted in order to explore the data and investigate whether a questionnaire employed to measure pre-service teachers' cognitive load could distinguish the three categories of cognitive loads (intrinsic, extraneous, and germane). The Principal axis factoring with "Direct Oblique Oblimin" rotation was applied for extracting the factors, while the coefficients were sorted by size, and all those less than 0.3 were suppressed.

6.4 Results

6.4.1 Preliminary results

Pre-service teachers' prior diagnostic knowledge

Table 9 displays the descriptive statistics for pre-service teachers' scores on the diagnostic knowledge test before and after intervention. To test for independence between pre-service teachers' prior diagnostic knowledge (a covariate) and an instructional approach (independent variable), the researcher applied One-way ANOVA. Results obtained show no significant difference in the prior diagnostic knowledge between experimental groups as well as the control group, $F(2, 78) = 0.708$, $p = .490$. These results implied that on average pre-service teachers' prior diagnostic knowledge was roughly equal in all three groups before intervention. Therefore, it was used as a covariate to explain part of unexplained variance, but not that one explained by manipulation of an instructional approach. That is, pre-service teachers' prior diagnostic knowledge as a covariate was supposed to be independent from the treatment effect. In other words, this was an important criterion in this intervention because in order to test whether the manipulation of an instructional approach has an effect on improving pre-service teachers' diagnostic competence, their prior diagnostic knowledge before intervention should be roughly equal.

Table 9: *Descriptive statistics for pre-service teachers' scores on the knowledge test before and after intervention to enhance the diagnostic competence in Physics misconceptions*

Experimental group	Pre-testing		Post-testing	
	Mean	SD	Mean	SD
Problem solving (n = 27)	20.67	5.14	26.93	4.32
Example-based learning (n = 28)	19.21	5.59	21.75	6.11
Control group (n =26)	20.92	6.42	20.58	6.87

6.4.2 Effects of problem solving and example-based learning on enhancing diagnostic competence (*RQ1*)

Table 10 displays the descriptive statistics for pre-service teachers' knowledge test scores after intervention to enhance their diagnostic competence in form of conceptual and procedural knowledge on identifying pupils' misconceptions in Physics. A MANOVA statistical test with an instructional approach in two levels as an independent variable, and diagnostic competence in form of conceptual and procedural knowledge measured as two dependent variables after intervention, was applied to test for the effects of problem solving and example-based learning instructional approaches on enhancing pre-service teachers' diagnostic competence (*RQ1*). Using Pillai's trace, this multivariate statistical test revealed a significant effect of the instructional approaches on enhancing pre-service teachers' diagnostic competence in identifying pupil's Physics misconceptions, $V = 0.26$, $F(4, 156) = 5.71$, $p < .001$, *Partial* $\eta^2 = .13$. Furthermore, the separate unvariate ANOVA tests for between-subjects effects revealed a significant effect of the instructional approaches on enhancing pre-service teachers' conceptual knowledge, $F(2, 78) = 12.24$, $p < .001$, *Partial* $\eta^2 = .24$; but non-significant effect on enhancing their procedural knowledge after intervention, F (2, 78) = 1.46, $p = .240$.

Including pre-service teachers' prior diagnostic knowledge as a covariate in the model, a MANCOVA statistical test with an instructional approach in two levels as an independent variable, diagnostic competence in form of conceptual and procedural knowledge as two dependent variables, were applied to test for the effects of problem solving and example-based learning instructional approaches on the pre-service teachers' diagnostic competences through an intervention *(RQ1)*. Using Pillai's trace, MANCOVA also revealed a higher significant effect of the instructional approaches on enhancing pre-service teachers' diagnostic competence, $V = 0.33$, $F(4, 154) = 7.63$, $p < .001$, *Partial* $\eta^2 = .17$. The separate univariate ANCOVA tests also revealed a significant effect of the instructional approaches on enhancing pre-service teachers' conceptual knowledge after including their prior diagnostic knowledge as covariate in the analysis, $F(2, 77) = 17.82$, $p < .001$, *Partial* $\eta^2 = .32$; but a non-significant effect on the procedural knowledge after intervention, $F(2, 77) = 1.19$, $p = .310$. However, the covariate, pre-service teachers' prior diagnostic knowledge in diagnosing pupil's misconceptions in Physics was significantly related to their conceptual knowledge after intervention, $F(1, 77) = 37.3$, $p < .001$, $r = .57$, as well as their procedural knowledge after intervention, $F(1, 77) = 20.62$, $p < .001$, $r = .46$.

Table 10: *Descriptive statistics for pre-service teachers' conceptual and procedural knowledge test scores on how to identifying pupil's Physics misconceptions after intervention*

Instructional method	Conceptual knowledge		Procedural knowledge	
	Mean	SD	Mean	SD
Problem solving (n = 27)	18.11	3.46	8.81	2.62
Example-based learning (n = 28)	14.36	4.54	7.39	3.18
None (n =26)	12.65	4.28	7.92	3.49

Furthermore, the MANOVA statistical test was followed up with discriminant analysis in order to find out how the discriminant functions could differentiate the experimental groups from a control group with respect to conceptual and procedural knowledge. The results obtained revealed two discriminant functions. The first explained 95% of the variance, canonical $R^2 = 0.24$, whereas the second explained only 5% variance, canonical $R^2 = 0.02$. In combination, these discriminant functions significantly discriminated the treatment groups, Wilks' lambda $\Lambda = 0.75$, $X^2(4) = 22.44$, $p < .001$, but removing the first function indicated that the second function did not significantly differentiate the treatment groups, Wilks' lambda $\Lambda = 0.98$, $X^2(1) = 1.27$, $p = .260$.

The correlations between outcome measures and the discriminant functions revealed that conceptual knowledge loaded very highly onto the first function (r = .99), and very slightly onto the second function (r = .03); procedural knowledge loaded very lowly onto the first function (r = .27) and very highly onto the second function (r = .96). The discriminant function plot in Figure 8 displays the first function discriminating both problem solving and example-base treatment groups from the control group, whereas the second function only slightly differentiates example-base learning treatment group from problem solving group.

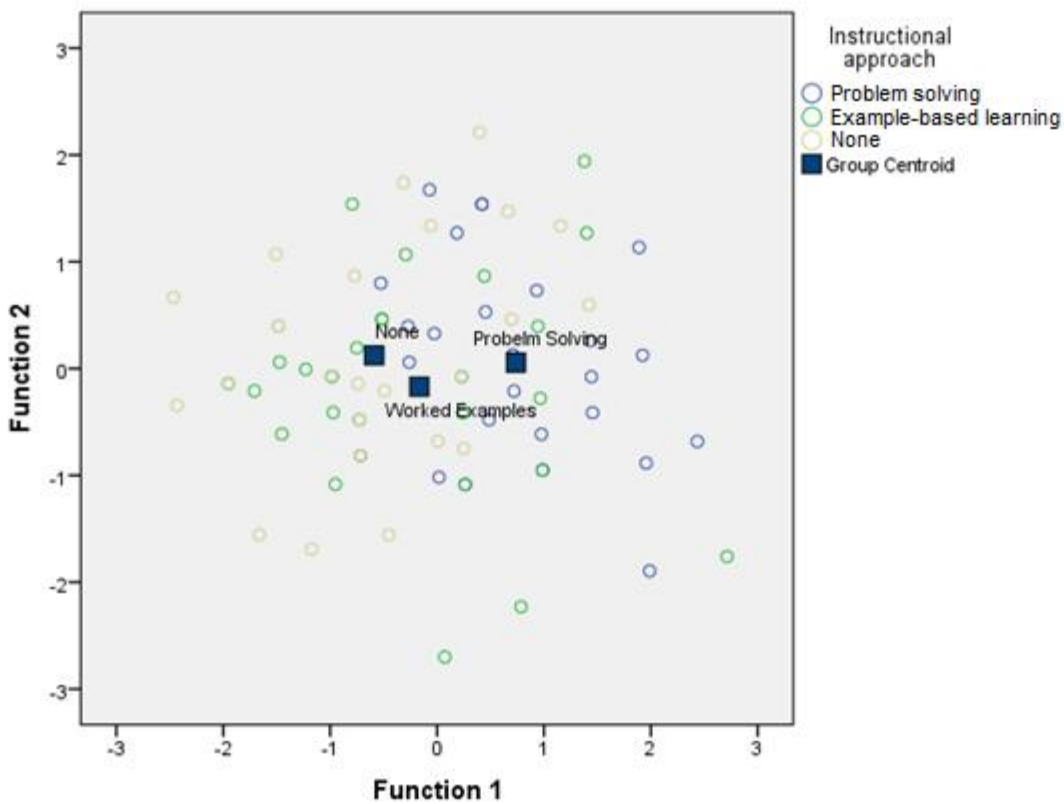


Figure 8. Canonical discriminant functions plot to discriminate between experimental groups and the control group.

6.4.3 Contrasts between instructional approaches on enhancing diagnostic competence (*RQ2*)

Descriptive statistics in Table 10 also compares the effectiveness of instructional approaches on the enhanced pre-service teachers' diagnostic competence in form of conceptual and procedural knowledge after intervention. Alternatively, the simple standard contrasts on the SPSS were applied to examine the differences between problem-solving and example-based learning instructional approaches on enhancing pre-service teachers' diagnostic competence (*RQ2*). The simple standard contrasts in MANOVA revealed that problem solving instructional approach had significantly enhanced pre-service teachers' conceptual knowledge when compared to those who did not receive any training (control group), t(78) = 4.82, $p < .001$, $r = .48$, while example-based learning instructional approach did not significantly enhance pre-service teachers' conceptual knowledge when compared to those who did not receive any training (control group), t(78) = 1.52, $p = .130$, $r = .20$. On the other hand, the same standard contrasts revealed that problem solving instructional approach did not significantly enhance pre-service teachers' procedural knowledge when compared to those who did not receive any training, t(78) = 1.04, $p = .300$, $r = .11$, and also example-based learning did not significantly enhance their procedural knowledge when compared to the control group, t(78) = -0.63, $p = .530$, $r = .07$.

Furthermore, the planned contrasts show that problem solving and example-based learning instructional approaches (both treatment groups) significantly enhanced pre-service teachers' conceptual knowledge when compared to a control group, t(78) = 3.65, $p < .001$, $r = .38$ (one-tailed), and that problem solving significantly enhanced pre-service teachers' conceptual knowledge when compared to example-based learning, t(78) = 3.38, $p < .001$, $r = .36$ (one-tailed). On the other hand, the planned contrasts revealed that problem solving and example-based instructional approaches (both treatment groups) did not significantly enhanced pre-service teachers' procedural knowledge when compared to a control group, t(78) = 0.24, $p = .404$, $r = .03$ (one-tailed), and that problem solving did not significantly enhance pre-service teachers' procedural knowledge when compared to example-based learning, t(78) = 1.70, $p = .047$, $r = .19$ (one-tailed).

6.4.4 Correlation between diagnostic competence and cognitive load (*RQ3*)

The bivariate correlation using Pearson correlation was computed in order to find out whether there was a relationship between pre-service teachers' diagnostic competence in form of conceptual or procedural diagnostic knowledge after intervention and the cognitive loads (intrinsic, extraneous, germane) that were encountered during intervention (*RQ3*). Table 11 presents a summary of the Pearson correlation coefficients between diagnostic knowledge and overall cognitive load encountered due to instructional approaches or learning tasks during an intervention. In this case, a Pearson correlation coefficient value of 0.1 represented a small effect, 0.3 is a medium effect and 0.5 is a large effect according to Cohen (1988).

Table 11: *Pearson correlation coefficients between diagnostic knowledge and overall cognitive load encountered during an intervention to enhance diagnostic competence.*

	CK	PK	Intrinsic CL	Extraneous CL	Germane CL
CK	1	0.33**	-0.16	-0.17	0.28*
PK		1	-0.05	-0.15	0.35**
Intrinsic CL			1	0.55**	-0.08
Extraneous CL				1	-0.25*
Germane CL					1

CK = Conceptual Knowledge, PK = Procedural Knowledge, CL = Cognitive Load
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson correlation coefficients (see Table 11) indicate that pre-service teachers' conceptual knowledge after intervention was significantly related to their procedural knowledge, r = .33, BCa 95% *CI* [0.14, 0.51], p < .01. Likewise, their conceptual knowledge after intervention was significantly related to germane cognitive load, r = .28, BCa 95% *CI* [0.06, 0.47], p < .05. However, the results obtained show that pre-service teachers' conceptual knowledge after intervention negatively correlated with intrinsic cognitive load, r = -.16, BCa 95% *CI* [-0.32, 0.03], p = .160, as well as to extraneous cognitive load, r = -.17, BCa 95% *CI* [-0.34, 0.02], p = .140.

Similarly, the results show that there was negative correlation between pre-service teachers' procedural knowledge after intervention and intrinsic cognitive load, r = -0.05, BCa 95% *CI* [-0.26, 0.18], p = .650, as well as with extraneous cognitive load, r = -.15, BCa 95% *CI* [-0.37, 0.08], p = .170. In contrast, pre-service teachers' procedural knowledge after intervention positively correlated with the germane cognitive load, r = .35, BCa 95% *CI* [0.19, 0.49], p < .01.

On the other hand, pre-service teachers' intrinsic cognitive load significantly correlated with extraneous cognitive load, r = .55, BCa 95% *CI* [0.37, 0.72], p < .001, while intrinsic cognitive load negatively correlated with germane cognitive load, r = -.08, BCa 95% *CI* [-0.26, 0.09], p = .460, whereas, also their extraneous cognitive load negatively correlated with the germane cognitive load after intervention, r = -.25, BCa 95% *CI* [-0.43, -0.07], p < .05. The negative correlations are also important because theoretically, we must minimize both intrinsic and extraneous loads during a learning process if our desire is to obtain high learner's performance.

6.4.5 Effects of the problem solving and example-based learning on cognitive load (*RQ4*)

Table 12 displays the descriptive statistics for the overall cognitive loads encountered during an intervention to enhance pre-service teachers' diagnostic competences in identifying pupils' Physics misconceptions. A MANCOVA was applied to test for the effect of problem solving and example-based learning instructional approaches on pre-service teachers' cognitive load encountered during an intervention to enhance their diagnostic competence (*RQ4*). Using Pillai's trace, this multivariate test statistics indicates that the instructional approaches had significantly influenced pre-service teachers' cognitive load encountered during an intervention, $V = 0.21$, F (6, 152) = 2.97, $p < .010$, Partial $\eta^2 = .11$. Also, the separate univariate ANCOVA tests revealed a significant effect of the instructional approaches on pre-service teachers' intrinsic cognitive load, F (2, 77) = 4.86, $p = .010$, *Partial* $\eta^2 = .11$, extraneous cognitive load, F (2, 77) = 5.44, $p < .010$, *Partial* $\eta^2 = .12$, and on germane cognitive load, F (2, 77) = 3.15, $p < .050$, *Partial* $\eta^2 = .08$ after including their prior diagnostic knowledge as a covariate in the analysis. However, the covariate, pre-service teachers' prior diagnostic knowledge was not significantly related to intrinsic cognitive load, F (1, 77) = 0.57, $p = .450$, $r = .09$, and to their extraneous cognitive load, F (1, 77) = 1.26, $p = .270$, $r = .13$, although it was significantly related to germane cognitive load, F (1, 77) = 5.78, $p < .05$, $r = .26$.

Furthermore, the simple standard contrasts revealed that problem solving instructional approach had not significantly influenced pre-service teachers' overall intrinsic cognitive load when compared to those who did not receive any training (control group), t (77) = 1.04, $p = .300$, $r = .12$; whereas example-based learning instructional approach had significantly influenced pre-service teachers' overall intrinsic cognitive load when compared to those who did not receive any training (control group), t (77) = 3.06, $p < .050$, $r = .33$. Likewise, the same standard contrasts revealed that problem solving did not significantly influence pre-service teachers' overall extraneous cognitive load when compared to those who did not receive any training, t (77) = 1.15, $p = .250$, $r = .13$; whereas example-based learning instructional approach had significantly influenced pre-service teachers' overall extraneous cognitive load when compared to those who did not receive any training (control group), t (77) = 3.25, $p < .050$, $r = .35$. However, problem solving did not significantly influence pre-service teachers' overall germane cognitive load when compared to those who did not receive any training, t (77) = 0.85, $p = .400$, $r = .10$; likewise, problem solving did not significantly influence pre-service teachers' overall germane cognitive load when compared to those who did not receive any training (control group), t (77) = -1.59, p = .070, r = .18.

Table 12: *Descriptive statistics for pre-service teachers' overall cognitive load encountered during intervention to enhance diagnostic competences in Physics misconceptions.*

Instructional method	Intrinsic cognitive load		Extraneous cognitive load		Germane cognitive load	
	Mean	SD	Mean	SD	Mean	SD
Problem solving (n = 27)	9.37	8.74	5.63	5.43	40.09	6.40
Example-based learning (n = 28)	13.88	8.31	9.57	8.12	31.43	14.61
None (n = 26)	7.12	5.97	3.54	5.50	37.50	13.46

6.4.6 Indirect effects of problem solving and example-based learning on diagnostic competence through cognitive load (RQ5)

A regression analysis through PROCESS method as described by Hayes was applied to test for the indirect effects of problem solving and example-based learning instructional approaches on the pre-service teachers' diagnostic competences through cognitive load as a mediator (*RQ5*). A regression analysis revealed insignificant indirect effects of the instructional approaches on pre-service teachers' diagnostic competence after intervention in relation to their cognitive loads. Table 13 presents the unstandardized and standardized indirect effects of the instructional approaches on pre-service teachers' diagnostic competences through cognitive loads after intervention.

Table 13: *The unstandardized and standardized indirect effects of problem solving and example-based learning on pre-service teachers' diagnostic competences through cognitive loads after intervention.*

Cognitive load	*B*	95% *CI*	*b'*	95% *BCa CI*
Intrinsic	0.16	[-0.14, 0.64]	0.02	[-0.02, 0.08]
Extraneous	0.23	[-0.09, 0.84]	0.03	[-0.01, 0.1]
Germane	-0.23	[-0.84, 0.31]	-0.03	[-0.1, 0.04]

b = Regression coefficient (unstandardized indirect effect),
b' = Index of Mediation (completely standardized indirect effect).
CI = Confidence interval, BCa = Bias corrected and accelerated.

Intrinsic cognitive load as a mediator

Mediation analysis revealed an insignificant indirect effect of the instructional approaches or methods on pre-service teachers' diagnostic competences in relation to intrinsic cognitive load, *b* = 0.16, *CI* [-0.14, 0.64]. The regression coefficient for completely standardized insignificant indirect effect of instructional method on pre-service teachers' diagnostic competence represents a smaller effect, *b* = 0.02, 95% BCa *CI* [-0.02, 0.08].

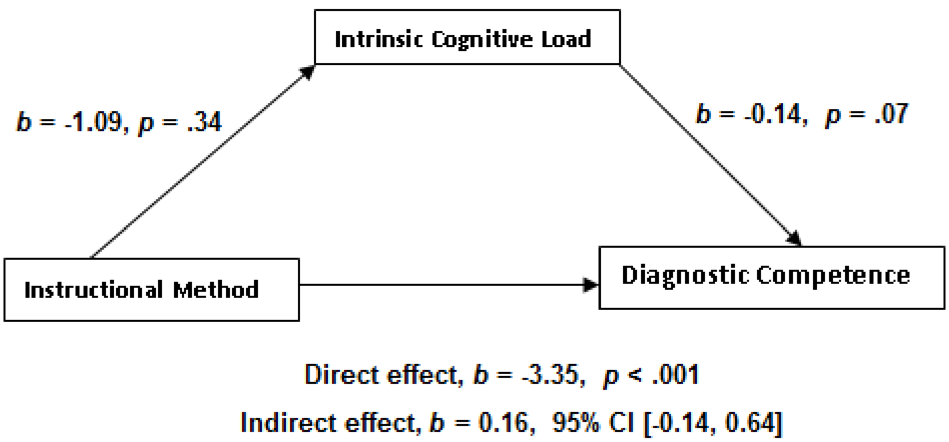


Figure 9. Mediation effect of intrinsic cognitive load.

Extraneous cognitive load as a mediator

Mediation analysis also revealed insignificant indirect effect of instructional method on pre-service teachers' diagnostic competences in relation to extraneous cognitive load, *b* = 0.23, *CI* [-0.09, 0.84]. The regression coefficient for completely standardized indirect effects of instructional method on pre-service teachers' diagnostic competences represents a positive smaller effect, *b* = 0.03, 95% BCa *CI* [-0.01, 0.1].

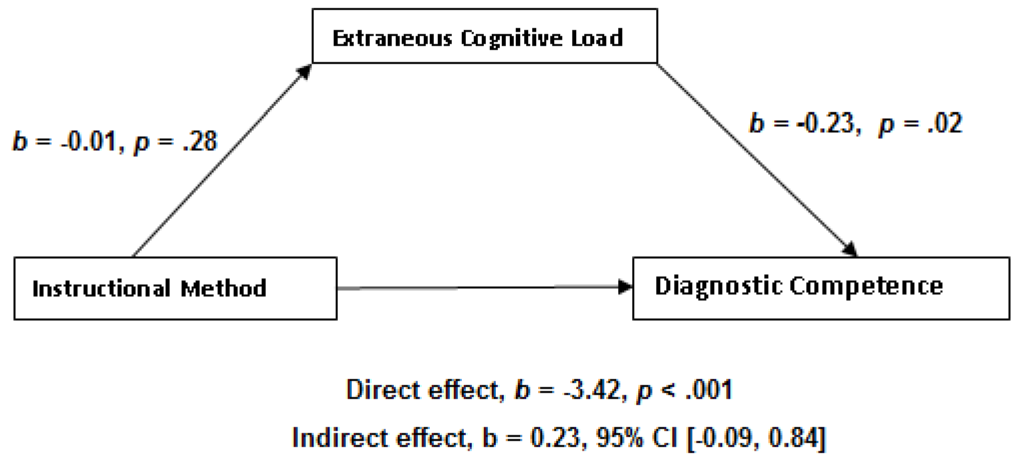


Figure 10. Mediation effect of extraneous cognitive load.

Germane cognitive load as a mediator

Mediation analysis revealed insignificant indirect negative effect of instructional method on pre-service teachers' diagnostic competence in relation to germane cognitive load, b = -0.23, *CI* [-0.84, 0.31]. The regression coefficient for completely standardized indirect effects of instructional method on pre-service teachers' diagnostic competences also represents a negative effect, b = - 0.03, 95% BCa *CI* [-0.1, 0.04].

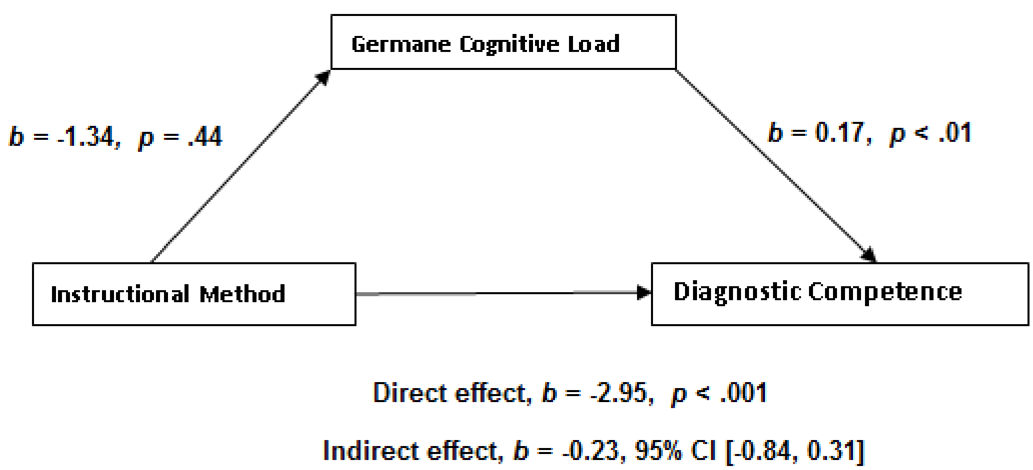


Figure 11. Mediation effect of germane cognitive load.

6.4.7 Extent to which the adopted questionnaire differentiates three types of cognitive load (*RQ6*)

An explanatory factor analysis (FA) was conducted in order to examine the data and find out whether the adopted rating scale questionnaire could differentiate the three types of cognitive load during an intervention to enhance pre-service teachers' diagnostic competence (*RQ6*). Then, a principal axis factor analysis was applied on the 13 items with oblique rotation (direct Oblimin and Kaiser Normalization covering 9 iterations). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis in this study, KMO = 0.81 and all KMO values for individual items were greater than 0.69, a value which is well above the acceptable limit of 0.5 (see notes from Field, 2013; *p*. 695). The minimum anti-image correlation diagonal value was 0.69, while the maximum value was 0.88. This statistics provides the relationship between covariance and correlations of data matrices and it should be above 0.5 (Field, 2013). Figure 10 shows a screen plot that would be used for identifying these factors. According to a plot, the point of inflexion seems to occur at third data point, and suggests retaining two factor solutions after oblique rotation.

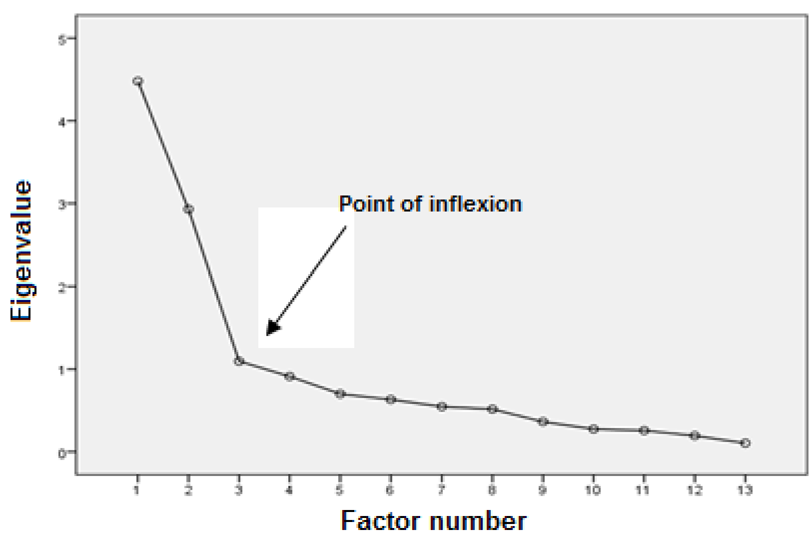


Figure 12. Screen plot for identifying the factors.

Then, an initial analysis was ran in order to obtain eigenvalues for each factor in the data. The model attempted to extract three factors, which had eigenvalues over Kaiser's criterion of 1, while in combination it explained 65.41% of the variance. The screen plot (see Figure 12) was a bite unclear and seemed to indicate an inflexion at third data point that would then justify retaining only two factors. However, due to eigenvalues for each factor being greater than 1, three factors were retained although the sample size seems to be smaller than ten times the number of items required (Leppink et al., 2014), as well as, the convergence of the screen plot and Kaiser Criterion on this value. Table 14 shows the factor loadings after rotation. The items that cluster on the same factor suggest that the first factor represents a germane cognitive load, the second factor, an extraneous cognitive load, and the third factor, an intrinsic cognitive load although one item from this factor appears to overlap on the second factor.

Table 14: *Factor loadings after rotation.*

	Rotated Factor Loadings(*N*=81)		
Item	Germane CL	Extraneous CL	Intrinsic CL
This activity really enhanced my knowledge of the terms that were mentioned.	**0.886**		
This activity really enhanced my knowledge and understanding of how to deal with the problems covered	**0.872**		
This activity really enhanced my understanding of the problems that were covered.	**0.870**		
This activity really enhanced my understanding of the content that was covered.	**0.750**		
I invested a very high mental effort during this activity in enhancing my knowledge and understanding	**0.689**		
The explanations and instructions in this activity were very unclear.		**0.656**	
I invested a very high mental effort in unclear and ineffective explanations and instructions in this activity.		**0.644**	
The explanations and instructions in this activity were, in terms of learning, very ineffective.		**0.557**	
The explanations and instructions in this activity were full of unclear language.		**0.502**	
I invested a very high mental effort in the complexity of this activity.		0.444	
In this activity, very complex terms were mentioned.		0.432	**-0.380**
The problem/s covered in this activity was/were very complex.			**-1.012**
The content of this activity was very complex.			**-0.605**
Eigenvalues	4.48	2.93	1.1
% of Variance	34.46	22.53	8.42
Cronbach values, α	0.91	0.69	0.74

Note. CL = Cognitive load

6.5 Discussion

The current study has revealed that both problem-solving and example-based learning instructional approaches significantly enhanced pre-service teachers' diagnostic competence in the form of conceptual knowledge. Thus, one of the remarkable finding in this study is that both instructional approaches significantly enhanced pre-service teachers' diagnostic knowledge in the form of conceptual diagnostic knowledge, but not the procedural knowledge. One of the possible explanations for this observation is that maybe during the learning phase of an intervention, pre-service teachers could have learned much more about the abstract concepts of how to identify pupils' misconceptions in Physics than the procedures on how to identify them. Alternatively, we can also explain this observation in terms of learning transfer. That is, it is possible that pre-service teachers had attained the learning transfer of the abstract concepts and ideas on how to diagnose pupils' misconceptions in Physics earlier than on the procedures. This is because the diagnostic knowledge was measured immediately after intervention, or because the instructional approaches provided scaffolds that could have enhanced the learning of the concepts and ideas on identifying pupils' misconceptions faster than the procedures (Hsu et al., 2015).

Moreover, the findings from this study have revealed that problem solving instructional approach is more effective than example-based learning on enhancing pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics. The effectiveness of problem solving over example-based learning also has been remarkable particularly in regards to the conceptual diagnostic knowledge but not to the procedural knowledge. These findings might be due to the fact that learning through problem solving instructional approach has facilitated development of conceptual knowledge about diagnosing misconceptions quicker than example-based learning (Hsu et al., 2015) because of scaffolding that might have been provided in the problem solving condition. Moreover, because pre-service teachers were allowed to discuss some ideas about diagnosis during the intervention, then collaboration might have enhanced learning through solving problems than studying examples, although pre-service teachers in both conditions were allowed to discuss some unclear models of solutions during the learning phase of an intervention (Retnowati et al., 2017).

Furthermore, the design features of the learning materials (models of Diagnoser tools) applied during the training phase of an intervention might have modulated the effectiveness of problem solving on enhancing pre-service teacher' diagnostic competences over example-based learning instructional approach. That is, the ‘Diagnoser tools’ used for training pre-service teachers on how to diagnose pupils’ Physics misconceptions in the problem solving experimental condition seem to have less elements interactivity than those used in the example-based learning experimental condition. Thus, pre-service teachers in the problem-solving experimental condition could have experienced less intrinsic cognitive load that had increased the germane cognitive load; which could lead to higher learning outcomes than those in example-based learning experimental condition (van Merriënboer & Sweller, 2010; Sweller, 1994). Therefore, we can assume that pre-service teachers who received problem-solving instructional approach had gained more knowledge on the concepts about identifying pupils’ Physics misconceptions than those who received example-based learning. We can also argue that pre-service teachers in the example-based learning experimental condition might have learned less abstract concepts in identifying pupils’ misconception due to high intrinsic cognitive loads (unnecessary mental load) imposed during the learning tasks (van Merriënboer & Sweller, 2005). Also, the learning materials in example-based learning experimental condition might have involved many elements’ interaction for pre-service teachers to integrate them as compared to first condition (e.g. examples of solutions vs. problems) during the learning task, that in one way, could have increased their extraneous cognitive load (van Merriënboer & Sweller, 2010). However, both instructional approaches seem to have no significant effect on pre-service teachers’ procedural knowledge of identifying pupils’ misconceptions after an intervention.

Nevertheless, the findings from this study seem to align with the “Expertise-reversal effect” which explains about the effectiveness of the minimally guided instructional approaches and the highly guided instructional approaches with regard to different learners’ prior knowledge (Sweller et al., 2003). According to Sweller and his colleagues, instructional approaches that are more effective with learners of low prior knowledge, can lose their effectiveness or even have negative consequences if applied to learners with high prior knowledge. In addition, the findings from this study have revealed that pre-service teachers’ diagnostic competence in the form of conceptual knowledge and procedural knowledge negatively correlated with intrinsic and extraneous cognitive loads, while correlating positively with germane cognitive load. The findings imply that, for pre-service teachers to gain more conceptual knowledge or procedural diagnostic knowledge, we should decrease their intrinsic or extraneous cognitive loads, while in contrast increasing their germane cognitive load (Sweller, 1994; van Merriënboer & Sweller, 2010) would facilitate higher learning. In this context, one can see that example-based learning instructional approach significantly increased both pre-service teachers' intrinsic and extraneous cognitive loads when compared to problem solving that had low effect on these two categories of cognitive load. The learning materials in the second experimental condition appeared to have higher elements interactivity, and so do the manner in which their presentation is done as compared to the first experimental condition.

Moreover, the findings show that there was significant relationship between intrinsic and extraneous cognitive loads, which represents the mental effort allocated to overcome the intrinsic nature of the learning materials, and the manner of presenting them respectively (van Merriënboer and Sweller, 2010). The correlation between two forms of cognitive load may imply that the manner in which learning materials are presented had close relationship with their nature during the training intervention. That is, maybe the design features of the 'Diagnoser tools' had close relationship with the manner of presenting them during the learning phase. Moreover, the findings in this study indicate that both intrinsic and extraneous cognitive loads had negatively correlated with germane cognitive load. This was an interesting finding because the literature (e.g. van Merriënboer & Sweller, 2010; Sweller et al., 1998) suggests that appropriate instructional procedures should lower extraneous cognitive load and increase germane cognitive load during the learning task. During the learning task of how to diagnose pupils' misconceptions, extraneous cognitive load would negatively correlate with germane cognitive load if meaningful learning was supposed to happen.

Furthermore, the findings indicate that both instructional approaches significantly influenced the cognitive load that pre-service Physics teachers encountered during the learning phase of the intervention. It appears that pre-service teachers in the example-based learning experimental condition encountered higher intrinsic and extraneous cognitive loads than those in the problem solving condition. This is probably due to the design features of the learning materials and the instructional support provided in the example-based learning condition during the training phase of an intervention. That is, because learners had to integrate many elements (e.g. studying example solutions versus problems), or received improper instructional support, this situation had possibly imposed high mental load that resulted in high intrinsic and extraneous cognitive loads. On the other hand, it was indicated that learning materials which employ worked examples can cause high element interactivity that can rise up their extraneous cognitive load, and hence overload the working memory during the learning process (Chen et al., 2016). Then, high extraneous load might have negatively influenced the learning process on how to diagnose pupils’ Physics misconceptions through studying examples of solution provided in the Diagnoser tools.

The findings from this study further indicate that cognitive load did not mediate the effect of the instructional approaches on enhancing pre-service teachers’ diagnostic competences. However, there was an interesting finding about the insignificant indirect effects of the instructional approaches on pre-service teachers’ diagnostic competence through extraneous and germane cognitive loads. That is, the indirect effect through extraneous cognitive load was in opposite direction to that through germane cognitive load. This observation was expected theoretically, since the literature shows that well designed instructional approaches should lower extraneous cognitive load, while increasing germane cognitive load (Sweller et al., 1998).

Finally, the findings obtained indicate that the adopted rating scale questionnaire to measure pre-service teachers’ cognitive load had differentiated the three types of items that were intended to measure three types of cognitive load, although two items to measure intrinsic load also appeared in extraneous load. These observations may imply that it is still difficult to differentiate between intrinsic and extraneous cognitive loads (Jong, 2010; Kalyuga, 2011). Although, the screen plot suggested a two factors solution on the left side of the point of an inflexion (see Figure 12); all the three factors were retained because eigenvalues for each factor was greater than 1. This situation indicates a considerable “amount of variations that could be explained by each factor after oblique rotation” (Field, 2013, p. 677). However, even though the current sample size was less than the required one (N = 130) (10 times the number of items, the factor analysis using current sample size (N = 81) in this study showed evidence of three factors solution.

Some factors have limited the findings from this study. First and foremost, the random or systematic errors (e.g. effect of extraneous variables) that might have occurred during an intervention. That is, although the researcher randomly assigned the pre-service teachers to different experimental groups before the intervention, this process might have not completely controlled the random errors due to extraneous variables (Creswell, 2012). For instance, pre-service teachers’ individual ability that might have contributed to the performance of knowledge tests among some pre-service teachers in the assessment of outcome measure (diagnostic knowledge gain) rather than the interventional treatment. To minimize the problem, the researcher assigned pre-service teachers randomly to different experimental groups and a control group before intervention, although some effects due to their individual ability might have contributed to their final score. Secondly, the length of interventional treatment for some pre-service teachers might have not been long enough to enable them to learn how to diagnose pupils' misconception in Physics. That is, some pre-service teachers might have required longer time to practice diagnosis (slow learners) than others (fast learners) according to individual ability or intelligence. To deal with the issue, the researcher carried out a longer intervention than most of other interventions within two training sessions.

Another possible factor that might have limited the findings with respect to second study is the measurement of pre-service teachers' diagnostic competence before and after intervention through an objective test. An objective test might have not been sufficient to measure pre-service teachers' diagnostic competence due to some systematic errors when constructing it. To minimize the problem, the researcher increased its validity through piloting the study, removing items with low correlations, and excluding some of the items that lowered the reliability of the test (Cronbach alpha) during the scale formation.

In conclusion, we can argue that problem-solving instructional approach is better than example-based learning in enhancing pre-service teachers' diagnostic competence in higher education. However, both instructional approaches seem to enhance pre-service teachers' diagnostic competence effectively if we minimize their intrinsic and extraneous cognitive loads, while increasing the germane cognitive load. Moreover, cognitive load seems not to be a significant mediator between the effect of an instructional approach and pre-service teachers' diagnostic competences during the learning process, although some non-significant indirect effect could be observed. Finally, it is possible to measure and differentiate three types of cognitive load through an adopted rating scale questionnaire, although it seems not to be easy to distinguish between intrinsic and extraneous cognitive loads.

The next chapter discusses the summary of studies, general discussions and conclusions.

CHAPTER SEVEN

SUMMARY OF THE STUDIES, GENERAL DISCUSSIONS AND CONCLUSIONS

7.0 Introduction

This chapter presents a summary of the two studies in this dissertation. In addition, it presents the summaries of discussions of the major findings, theoretical and practical implications. Also, this chapter presents limitations of the studies, conclusions with respect to the specific research questions and recommendation for further studies.

7.1 Summaries of the studies

The aim of this dissertation was to promote an understanding of how to enhance pre-service teachers' diagnostic competence in Physics misconceptions. Diagnostic competence in teacher education is important as far as formative assessment practice is concerned. This is because through diagnosis teachers can obtain the necessary information for decision making similarly to medical doctors who diagnose their patients before provide appropriate treatment. However, while it is necessary to enhance diagnostic competence for classroom teachers similarly to medical doctors, an issue remains about how best we can adapt instructional strategies to foster the development of diagnostic competence in medical education to teacher education. Also, how we can promote the development of this competence among classroom teachers through some prominent instructional approaches right from initial professional training programs is a crucial research issue. That is, how to facilitate diagnostic competence among undergraduate students of teacher education programs (pre-service teachers), similarly to medical students in which diagnostic competence is a basic curriculum requirement.

Furthermore, in the teaching and learning science at middle or high schools pupil's held misconceptions in science (e.g. Physics) is an issue. That is, if teachers do not identify science misconceptions and correct them during the learning process, they can hinder the learning of new science ideas (Gurel et al., 2015; Smith et al., 1994). Thus, Physics teachers among other science teachers are required to develope diagnostic competence in order to obtain information about pupils' held common misconceptions. The diagnosed information would then enable teachers to understand how pupils learn, facilitate pupils' conceptual change, and hence improve the leaning process of science (Chin, 2001; Morrison & Lederman, 2003; Treagust, 1988).

According to the literature, various empirical studies had been conducted in order to foster the development of diagnostic competences either in teacher or in medical education. These studies had applied experimental research designs and different interventions to enhance diagnostic competences among undergraduate students or inexperienced professionals. Also, the studies differed in terms of designs and instructional strategies that were applied during the learning phase of an intervention. As a result, interventions applied different instructional approaches in order to facilitate the learning process of how to diagnose various aspects. Thus, the first general research question was formulated as follows:

General research question 1:

"*To what effect can different instructional approaches foster the development of diagnostic competences through interventions?"*

The studies also varied in terms of effect sizes on fostering development of diagnostic competence or in terms of other within-study characteristics. Thus, one of the important issues to consider was the relationship between learner's prior knowledge and an instructional approach applied during the learning phase of the intervention. The literatures indicate that learning performance differs according to the type of an instructional approach and level of learners' prior knowledge. For instance, some researchers have argued that example-based learning instructional approach is appropriate for learners who have low prior knowledge (van Gog & Rummel, 2010; Renkl, 2014), whereas, problem solving is appropriate for learners with high prior knowledge (Kalyuga et al., 2001). The literatures also have determined that learner's prior knowledge can hinder or promote the learning of new knowledge depending on whether it is accurate or inaccurate, misleading or not misleading, and whether it relates to the required new knowledge (Thompson & Zamboanga, 2004). On the other hand, in case of learning new or complex skills, some cognitive researchers have shown that worked examples can be applied first at initial stages, then as learners gain enough conceptual knowledge, examples should be withdrawn, and let them continue solving problem on their own (Kalyuga et al., 2001). Another perspective also arises from other literatures which narrated that, the prior knowledge might not affect the learners' learning outcomes, but rather what learners can learn actually depends on individual ability or intelligency, or what is being taught (the content) and the situations of how the learning process occurs (Kuhn, 2007).

According to cognitive load theory, working memory capacity of human is limited and if certain learning activities impose high intrinsic or extraneous cognitive load, they can reduce mental load capacity and therefore hinder the learning process (Jong, 2010; Sweller, 1994). Thus, learning tasks or instructional approaches need to be designed so as to reduce unnecessary mental load, hence enhance working memory capacity, and avoid overloading student's mental capacity (van Merriënboer & Sweller, 2010; Sweller et al., 1998). However, researchers have indicated that some instructional approaches may influence students' cognitive load differently during the learning process, depending on the task or the design features of the materials or instructional approaches (Sweller, 1994). For instance, while example-based learning can lower students' extraneous load, problem solving that apply structured problems may impose high extraneous load (Sweller et al., 1998). Therefore, the following was another general research question about how instructional approaches could enhance the development of diagnostic competences with respect to other variables.

General research question 2:

"*How can the effect of instructional approaches on enhancing diagnostic competences be moderated or mediated by other variables?*"

Then, a meta-analysis was conducted in order to review empirical primary studies that was aimed at fostering the development of diagnostic competence through interventions in both teacher education and in medical education. A systematic review of the primary studies would enable the researcher in this dissertation to learn more about the moderation effect of some potential factors (e.g. instructional approach). A meta-analysis was deemed necessary in order to synthesize the findings from primary empirical studies that focused on enhancing the diagnostic competences through interventions (Viechtbauer & Cheung, 2010). Moreover, a meta-analysis would also enable the researcher to compute an estimate of overall or mean effect size, and hence investigate the influence of moderator variables with respect to this mean effect size. Therefore, specifically a meta-analysis was guided by the following research questions.

RQ1. To what overall effect size can the development of diagnostic competences among medical students, health practitioners, pre-service or in-service teachers be fostered though interventions?

RQ2. What is the moderation effect of (i) instructional approach (ii) prior knowledge (iii) experimental design, and (iv) domain; on the development of diagnostic competences through intervention?

RQ3. How does the moderation effect of the instructional approach applied in intervention to enhance diagnostic competence vary with the levels of the learners' prior knowledge?

The following databases were used to search for relevant primary studies focusing on enhancing diagnostic competence, and that would be included in the sample: PsycINFO, PsyINDEX, PsycARTICLES, ERIC and MEDLINE. About 2630 eligible articles were obtained from these databases. Four criteria were used to judge for inclusion:

1) A study must be empirical and aims to facilitate diagnostic competences through an intervention.
2) A study must use an experimental research design with at least one treatment condition.
3) The intervention must aim to facilitate diagnostic competence (defined as ability to engage in the goal oriented gathering and integration of information to make medical or educational decisions, COSIMA research group in press).
4) A study must provide statistical data to compute an effect size estimate in terms of standardized mean difference.

As a result, 22 studies and 43 effect sizes were included in the sample. All effect size estimates were computed in terms of standardized mean difference (Cohen's d) then finally converted into Hedge's g (unbiased estimate). The total number of participants from all relevant studies were 1954. All high-inference study characteristics (e.g. prior knowledge) and the effect sizes were double-coded by two independent raters. Data analysis applied meta-regressions, a random effect model, and robust variance estimation (RVE) method. The author applied correlated and hierarchical effects to estimate the overall effect size and perform moderator analysis respectively. The following were potential categorical moderator variables: problem solving (present/absent), example-based learning (present/absent) or direct instruction(present/absent), prior knowledge (high/low), experimental design (subjects random assignment/not), and domain (medical education/teacher education). Furthermore, an instructional approach moderator variable was coded: (problem solving/example-based/mixture).

A meta-analysis revealed a positive medium mean effect size (g = 0.37) on fostering the development of diagnostic competence through interventions in both domains. The findings from moderator analysis suggest that an instruction approach is a significant moderator when problem solving is applied (present) during the learning phase of an intervention. Moreover, the findings obtained from moderator analysis reveal that prior knowledge (low), experimental design (quasi), and domain (medical education) are significant moderators of the effect of intervention on fostering the development of diagnostic competence. In addition, the moderation effect of the interaction between example-based learning and prior knowledge (low) although had less degree of freedom than the required one, and between problem-solving and prior knowledge (high), are both significant moderators of the effect of intervention on diagnostic competence. Unexpectedly, the moderation effect of the interaction between the presence of example-based learning instructional approach and prior knowledge (high) seems to be a significant moderator, although this interaction effect has a negative small effect on the development of diagnostic competences through intervention.

The meta-analysis findings have implications both for theory and for practice. Theoretically: first, an instructional approach that involves problem solving especially by using cases can facilitate the development of diagnostic competences better than example-based learning or direct instruction. Secondly, learners' prior diagnostic knowledge seems to be a covariate of the effect of an instructional approach on fostering the development of diagnostic competences through interventions. In practice, the findings imply that learning tasks that involve solving problems during the learning phase of an intervention are better than those which employed direct instructions or example-based learning on enhancing diagnostic competences.

In conclusion, the current meta-analysis has revealed that we can advance the undergraduate students' or inexperienced professionals' diagnostic competences in the fields of teacher education or medical education through interventions and with a medium effect size. An instructional approach is a significant moderator if we apply problem solving in the process of how to diagnose various aspects both in medical and teacher education. Some other factors: learner's prior diagnostic knowledge, experimental design, and domain or contexts are potential moderator variables. Finally, a meta-analysis seems to justify the reconceptualization that example-based learning instructional approach can best fit learners with low prior knowledge, whereas, problem solving best fits the learners with high prior knowledge.

Regarding the findings from a meta-analysis, it was necessary to design an experimental study to further investigate about problem solving and example-based instructional approaches. That is, more information was required in order to add knowledge to the literature. The meta-analysis in the first study in this dissertation has revealed that problem solving is more effective than example-based learning on enhancing diagnostic competences probably because for complex learning goals, own experiences with diagnostic problems is necessary for the learners (Kalyuga et al., 2001). However, the primary studies in the meta-analysis (first study) indicate that example-based leaning also has been applied to foster the development of diagnostic competences with some significant effects especially with additional instructional support (Chamberland et al., 2015; Heitzmann et al. 2015; Peixoto et al., 2017; Stark et al., 2011). On the other hand, the literature also indicates that example-based learning might be the best instructional approach for learners of low prior knowledge or acquisition of new or complex skills (van Gog & Rummel, 2010; Renkl, 2014; Tuovinen & Sweller, 1999). However, for pre-service teachers at undergraduate level, an open question still remains about the effect at each instructional approach on enhancing diagnostic competence in identifying pupils' Physics misconceptions. In addition, due to contradiction findings in effect size on fostering diagnostic competences, it was necessary to compare their effects when it comes to enhancing pre-service Physics teachers' diagnostic competence.

Another important issue to investigate with respect to the second study was about the influence of other variables that could moderate or mediate the effect of instructional approach on pre-service teachers' diagnostic competences. For instance, the cognitive load that pre-service teachers might encounter during the learning process, is one of these variables (Sweller, 1994). However, learners may encounter cognitive load due to unnecessary mental load imposed by the learning materials (intrinsic load), or instructional procedures (extraneous load), or mental capacity advocated to deal with the intrinsic nature of the learning materials and that leads into learner's performance (germane load) (Paas et al., 2003; Sweller, 1994; Sweller et al., 1998).

However, problem solving and example-based learning instructional approaches can impose different amount of cognitive loads depending on the features of the learning materials or the manner in which we present them (Sweller et al., 1998). While the amount of cognitive load that pre-service teachers may encounter can mediate the effect of instructional approach on enhancing their diagnostic competence, some other extraneous factors, for instance learner's individual ability and other confounding variables may also influence the effect of an instructional approach. To approach these research questions scientifically, the researcher (author of this dissertation) in collaboration with his supervisors had designed an experimental study in order to address these research issues. The undergraduate Bachelor of Science (with education) students of one of the public university in Tanzania volunteered to participate in the study through asking their informed consents. Specifically, the seond study was guided by the following research questions.

RQ1: *To what effect can problem-solving and example-based learning instructional approaches enhance pre-service teachers' diagnostic competence in identifying pupil's misconceptions in Physics*?

RQ2*: How does problem solving instructional approach differ from example-based learning on enhancing pre-service teachers' diagnostic competence in identifying* Physics *misconceptions*?

RQ3: *What is the correlation between pre-service Physics teachers' diagnostic competence and cognitive load encountered during the intervention*?

RQ4: *To what effect does problem-solving or example-based learning instructional approach influence pre-service* Physics *teachers' cognitive load during an intervention*?

RQ5: *At what extent can cognitive load mediate the effect of problem solving or example-based learning on pre-service teachers' diagnostic competence*?

RQ 6*: To what extent can the adopted questionnaire differentiate the three types of cognitive load during the intervention to enhance pre-service teachers' diagnostic competence*?

The second study applied a between-group experimental research design, and a sample size (N = 81) of undergraduate Bachelor of Science (with education) students. These pre-service teachers were taking Physics as one of their major subject. Pre-service teachers in the treatment groups practised on how to diagnose pupil's misconceptions in Physics (Mechanics and Electricity) by using models of 'Diagnoser tools' as learning materials, and through either problem solving or example-based learning instructional approach, while the control group did nothing. Pre-service teachers in the control group participated in all other interventional procedures. A standardized multiple choice test measured the diagnostic competence in terms of conceptual and procedural knowledge, while a rating scale questionnaire adopted from Leppink et al. (2014), was used for measuring their cognitive load. Data were analysed through multivariate statistical tests because diagnostic competence was considered in the form of conceptual and procedural knowledge (two dependent variables), while instructional approach (problem solving and example based learning) was considered as an independent variable. Additionally, we used the following statistical tests: the bivariate correlation using Pearson correlation coefficients, mediation analysis by Hay's PROCESS, and a factor analysis to analyze the data.

An empirical study had revealed that both instructional approaches; problem solving and example-based learning had significantly enhanced pre-service teachers' diagnostic competence in the form of conceptual knowledge, but not the procedural knowledge. Moreover, the results obtained indicate that problem solving is more effective than example-based learning on enhancing pre-service teachers' diagnostic competence in Physics misconceptions. Furthermore, the results obtained show that pre-service teachers' diagnostic competence in the form of conceptual and procedural knowledge positively correlated with germane cognitive load, while it negatively correlated with intrinsic and extraneous cognitive load. On the other hand, the results obtained indicate that there was significant relationship between intrinsic and extraneous cognitive load, the constructs that represent mental load due to the intrinsic nature of the learning tasks or materials, and mental load due to the manner of presenting them. The results obtained also indicate that both intrinsic and extraneous cognitive loads had negatively correlated with germane cognitive load. The results further show that example based learning instructional approach had significantly influenced both intrinsic and extraneous cognitive loads. However, cognitive load did not significantly mediate the effect of the instructional approaches on enhancing diagnostic competences. Finally, factor analysis with the current sample of pre-service teachers revealed three factors that represented items intended to measure the germane, extraneous and intrinsic cognitive loads respectively.

7.2 General discussions of major findings

The meta-analysis findings have revealed that diagnostic competence among undergraduate students or inexperienced professionals can be facilitated through interventions and with a medium effect size. This implies that interventions can be used to foster the development of diagnostic competences with a moderate effect size. The size of the mean effect size might have depended on the effect sizes across the individual studies, which in turn depends on a number of other factors. For instance, the extent to which studies manipulated the independent variable in order to see the effect on the dependent variable or the settings of the experimental conditions when compared to the control condition. The moderator analyses have indicated that an instructional approach is a significant moderator variable if we apply problem solving, as well as, diagnostic problem cases during the learning process. For instance, some primary studies (Klug et al., 2016; Mamede et al., 2012) included in the sample of this meta-analysis indicate that learners who were provided with cases and practiced diagnosis through problem solving led to large observed positive effect sizes.

Moreover, the moderator analysis revealed that prior knowledge is a significant moderator variable if participants who have low prior knowledge are involved in the learning task of how to diagnose various aspects in both fields. This finding implies that even learners with low prior knowledge can also learn effectively with problem solving instructional approaches although theoretically they could learn more with example-based learning (Renkl et al., 2000; Renkl, 2014; Tuovinen, & Sweller, 1999). Furthermore, the findings obtained indicate that an experimental research design was a significant moderator variable through employing quasi experiments. The findings obtained imply that participants who were not randomized could have learned how to diagnose better with problem solving than those who were randomly assigned into different groups. However, the research methodology suggests that randomly assigning participants to different groups during an experiment can allow for more control of other random factors, for instance, personal ability (Creswell, 2012). In addition, the findings have indicated that domain medical education is a significant moderator variable and it implies that studies conducted at medical education field could have enhanced diagnostic competences among the participants better than the studies conducted in teacher education.

Another important finding in this meta-analysis was about the moderation effect of the interaction between the instructional approaches and the levels of learner's prior knowledge. That is, the moderation effect of the interaction between the presence of problem solving, the example-based learning or direct instruction and learners' prior knowledge. The findings obtained show that the moderation effect of the interaction between the presence of problem solving and high prior knowledge was a significant moderator. Likewise, the interaction effect between the presence of example-based learning instructional approaches and low prior knowledge seems to be a significant moderator even though the power for this interaction effect was too low for truly reliable results. These finding are in line with the theoretical perspectives which suggest that learners with high prior knowledge would learn better with the problem solving instructional approach, while those with low prior knowledge with example-based learning (Kalyuga, 2007; Kalyuga et al., 2001). According to Kalyuga and his colleagues, learners who have low prior knowledge may benefit much from instructional approaches that provide more guidance (e.g. example-based learning), while instructional approaches that encompass less guidance (e.g. problems solving) can best suit learners who have high prior knowledge. Thus, according to literature, the effectiveness of these instructional approaches that were employed in the learning phases of the studies included in this meta-analysis can be linked to the levels of learners' prior knowledge (Kalyuga et al., 2001).

On the other hand, the findings in the second study revealed that both instructional approaches had significant effects on enhancing pre-service teachers' diagnostic competence. That is, problem solving and example-based learning seem to had significantly enhanced pre-service teachers' diagnostic competence. However, both instructional approaches significantly enhanced pre-service teachers' diagnostic knowledge in the form of conceptual knowledge, but not the procedural knowledge. One of the possible explanations for this observation maybe the learning phase of the intervention; pre-service teachers could have learned more the abstract concepts on how to identify pupils' misconceptions in Physics than the procedures on identifying these misconceptions. Alternatively, we can argue that it is possible that pre-service teachers could have attained the near transfer of conceptual knowledge on how to diagnose pupils' misconceptions earlier than the procedural knowledge, since diagnostic knowledge was measured immediately after the intervention. Finally, the instructional approaches might had provided scaffolds, which in turn could had enhanced the learning of the concepts and ideas about diagnosing pupils' misconceptions in Physics more than the procedures (Hsu et al., 2015).

Another essential finding is that, problem-solving instructional approach was more effective than example-based learning in enhancing pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics. The effectiveness of problem solving has been remarkable particularly on the conceptual diagnostic knowledge but not the procedural knowledge. These findings might be due to learning through problem solving instructional approaches; and might have enhanced the development of conceptual knowledge about diagnosing misconceptions more than through example-based learning. The finding concurs with the argument that "learning is facilitated by the early rather than later use of explicit guidance through worked examples, and by providing learners with other information that require them to successfully solve transfer problems" (Hsu et al., 2015 p.37). Nevertheless, the findings from this study seem to align with the "Expertise reversal effect" which explains the effectiveness of the minimally guided instructional approaches and the highly guided instructional approaches with regard to different learners' prior knowledge (Sweller et al., 2003). According to Kalyuga and his colleagues, instructional approaches are much more effective for learners with low prior knowledge and can lose their effectiveness or even have negative effects if applied to learners with high prior knowledge.

The findings from the second study have also revealed that pre-service teachers' diagnostic competence in the form of conceptual knowledge and procedural knowledge negatively correlated with intrinsic and extraneous cognitive loads, and correlated positively with germane cognitive load. These findings imply that, as the pre-service teachers gain more conceptual knowledge or procedural diagnostic knowledge, their intrinsic or extraneous cognitive loads should be decreased, while their germane cognitive load should be increased (Sweller, 1994; Sweller et al., 1998). Thus, we have seen that example-based learning instructional approach had significantly increased pre-service teachers' intrinsic and extraneous cognitive loads when compared to problem solving. The learning materials in the second experimental condition appeared to have higher elements interactivity, and so did the manner in which they were presented as compared to the first experimental condition. Moreover, the findings obtained show that there was a significant relationship between intrinsic and extraneous cognitive loads, which represents the mental effort to overcome the intrinsic nature of the learning materials, and the manner in which learning materials are presented respectively (van Merriënboer & Sweller, 2010). The correlation between two forms of cognitive load may imply that the manner in which learning materials were presented has close relationship with the nature of the learning materials used during the training. That is, the design features of the 'Diagnoser tools' had a close relationship with the way in which they were presented. This is because learning materials that have high elements interactivity can impose high intrinsic cognitive load, and may be difficult to understand (Sweller, 1994).

In addition, the findings obtained in this study indicate that both intrinsic and extraneous cognitive loads had negatively correlated with germane cognitive load. This was an interesting finding because the literature (e.g. van Merriënboer & Sweller, 2010; Sweller et al., 1998) suggests that appropriate instructional procedures should lower extraneous cognitive load and increase germane cognitive load during the learning task. Thus as expected, during the learning task of how to diagnose pupils' misconceptions, extraneous cognitive load would negatively correlate with germane cognitive load if meaningful learning should happen. Furthermore, the findings obtained indicate that the pre-service teachers in the example-based learning experimental condition encountered higher intrinsic and extraneous cognitive loads than those who were trained with problem solving. The reason for this observation is probably due to the design features of the learning materials and the instructional support used in the example-based learning condition during the training phase. That is, because learners had to integrate many elements (e.g. studying example solutions versus problems), or received improper instructional support. This situation had possibly imposed high mental load which resulted in high intrinsic and extraneous cognitive loads. These findings also seem to align with the argument that learning materials that have high elements interactivity or are improperly presented can impose high intrinsic or extraneous cognitive load (Sweller, 1994). Other researchers have also argued that learning materials which employ worked examples can have high interactivity that might increase extraneous cognitive load, and which result in overloading the working memory during the learning process (Chen et al., 2016).

The second study findings further indicate that the cognitive load did not mediate the effect of the instructional approaches on enhancing pre-service teachers' diagnostic competences. Also, there was an interesting finding about those non-significant indirect effects of the instructional approaches on pre-service teachers' diagnostic competence through extraneous and germane cognitive loads. That is, the indirect effect through extraneous cognitive load was in opposite direction to that through germane cognitive load. This observation is inline with the past findings (Sweller et al., 1998) which showed that well designed instructional approaches should lower extraneous cognitive load, while increasing germane cognitive load, if really meaningful learning should occur as a result of instructional approach. Finally, the findings indicate that a rating scale questionnaire to measure pre-service teachers' cognitive load, could differentiate between the three types of cognitive load. That is, the questionnaire items showed three factors that represented the three types of cognitive load, although two items that were supposed to measure intrinsic load also appeared to measure extraneous load. This observations may imply that it is still difficult to differentiate between intrinsic and extraneous cognitive loads through this psychometric instrument (Jong, 2010; Kalyuga, 2011).

7.3 Theoretical and practical implications of the findings

The findings from both studies in this dissertation have both theoretical and practical implications. Thus, this subsection first describes the theoretical implications with respect to the development of diagnostic competences among undergraduate students, and the discussion of practical implications follows afterwards.

First, with respect to theoretical implications, the findings imply that the problem solving instructional approach can better fit the development of diagnostic competence among undergraduate students at higher education than example-based learning or direction instruction. For example, science education instructors can apply problem solving to enhance pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics during undergraduate teacher training programs rather than using example-based learning or direct instructional approaches. On the other hand, pre-service teachers at this level might have already gained enough content knowledge as well as pedagogical-content knowledge to enable them learning about how to diagnose pupils' misconceptions through the solving of problems better than direct teaching or using examples.

Secondly, another important theoretical implication is about learner's prior knowledge in relation to the type of instructional approach applied in the learning task. The findings imply that science education students at undergraduate level might require instructional approaches that provide minimum guidance (e.g. problem solving) during the learning process of how to diagnose various aspects. That is, at this stage of professional training/learning, pre-service teachers require those instructional approaches that involve learners solving diagnostic problems rather than studying examples or receiving direct teaching. In addition, with respect to pre-service teachers' diagnostic knowledge test scores before intervention (pre-test), it implies that pre-service teachers at undergraduate level might have already possessed some prior knowledge to enable them learning through minimum guided instructional approaches.

Thirdly, although an instructional approach had influenced pre-service teachers' cognitive load during the learning process, the cognitive load that was encountered seems to be a non-significant mediator between the effects of instructional approaches and pre-service teachers' diagnostic competence in identifying pupils' misconceptions in Physics. In addition, the findings imply that pre-service teachers may learn how to diagnose more effectively if we minimize intrinsic and extraneous cognitive loads, while maximizing the germane cognitive load. Finally, the findings also imply that we can measure the three types of cognitive load by using a rating scale questionnaire, although it seems that it is difficult to distinguish between intrinsic and extraneous cognitive loads.

On the other hand, the findings in this dissertation have some practical implications. First, regarding teacher-education training programs for undergraduate science teachers, integrating diagnostic practices into Physics-methods course curriculum during undergraduate training programs at university can enhance their formative assessment skills. That is, the prospective Physics teachers can learn how to identify pupils' Physics misconceptions as early as possible during initial training programs. Moreover, this curriculum development with significant effect can ensure early development of diagnostic competence in identifying pupils' misconceptions among the prospective Physics teachers. Then in future, when teaching they can apply this knowledge in identifying pupils' conception of Physics ideas, understand their learning processes, and hence improve their conceptual understanding.

Another vivid practical implication of the findings is based on the use of some modern online diagnostic tools available from some educational websites. For instance, both pre-service and in-service Physics teachers can apply the 'Diagnoser tools' (see http://www.diagnoser.com) in implementing classroom diagnostic learning environment. These diagnostic tools usually provide questions designed to elicit pupil's wrong conceptions of ideas for a particular topic or sub-topic in Physics. A 'Diagnoser' is a free online diagnostic tool that teachers can apply as long as they have internet access. Thus, applying this online tool, pre-service Physics teachers can develop diagnostic competence that can also help them to improve their formative assessment practices.

7.4 Limitations of the studies

There were some limitations with respect to the findings in both studies. Regarding meta-analysis, one of the limitations was about the restrictions of robust variance estimation (RVE) method especially when estimating meta-regressions for moderator analysis. For instance, less number of studies (< 40), as well as, less number of studies in teacher education category than in medical education could have affected the moderator analysis of domain factor because the studies might have not well balanced. That is, in th meta-analysis there was less number of studies in teacher education compared to medical education. This was due to less empirical studies in teacher education that qualified for inclusion in the sample compared to medical education. Then this might have affected the degrees of freedom and hence the power of the moderation effect of domain moderator variable.

Another potential limitation in the current meta-analysis is about the definitions of some moderator variables when determining their categories. That is, the definitions of the instructional approach, as well as, the definitions of levels of prior knowledge when categorizing the studies according to these moderator variables. For instance, the definitions of problem solving and example-based learning instructional approaches might be based on special features that distinguished them clearly than the one used in this meta-analysis. In the current meta-analysis, we defined the categories of the instructional approaches as well as for prior knowledge according to the context of this dissertation. Therefore, if we consider other definitions instead of these ones, we might end up in different categories of these moderator variables, and hence might produce different moderator analysis results.

With respect to the findings from the second study, one of the limitations was about the random errors that might occur due to extraneous variables. For instance, the individual ability or intelligence among pre-service teachers who participated in an intervention might have influenced the assessment of pre-service teachers' diagnostic competence after an intervention or even before. Although the researcher had randomly assigned pre-service teachers to different groups before an intervention, this might have not completely controlled the personal characteristics including individual ability, and therefore could have affected their diagnostic competence gain. That is, some intelligent or less intelligent pre-service teachers might had concentrated in one of the three groups and so affect the outcome even if the researcher applied random assignment. Alternatively, individual ability among the pre-service teachers might have affected their scores on diagnostic knowledge test. Therefore, the individual ability could have influenced the outcome measures rather than only the interventional treatment of instructional approach, and hence the findings too.

Another potential limitation with respect to the second study was about the measurement of pre-service teachers' diagnostic competence before and after intervention through the same objective test. That is, some pre-service teachers could have became familiar with some test items and therefore could had also affected the learning outcomes. However, the researcher ensured that some control measures were put in place; for instance the use of control group that could provide some more information about whether the interventional treatment had an effect on the pre-service teachers diagnostic competences after intervention or not.

7.5 Conclusions and recommendation for further studies

In this dissertation, the researcher has drawn the following general conclusions with respect to both studies conducted in order to investigate the process of enhancing diagnostic competence through interventions. According to the meta-analysis on empirical primary studies that focus on fostering the development of diagnostic compence in medical and teacher education, this competence can be enhanced through interventions and with a medium effect size. Moreover, we can advance diagnostic competence in the best way by employing problem-solving instructional approach. Also, this meta-analysis seems to justify the reconceptualization that example-based learning instructional approach can best fit learners with low prior knowledge, whereas, problem solving instructional approach best fit the learners with high prior knowledge.

According to the findings from the second study, we can also conclude that learners at higher education pre-service teachers can learn abstract concepts and ideas about diagnosis process better through problem solving than example-based learning instructional approach. In addition, both the problem solving and example-based learning instructional approaches seem to facilitate the learning process of how to diagnose various aspects if we minimize their intrinsic and cognitive loads, while increasing their germane cognitive load. Moreover, a cognitive load seems not to be a significant mediator between problem solving or example-based learning and pre-service teachers' diagnostic competences during the learning process, although both instructional approaches can significantly influence it. Lastly but not the least, we can measure the three types of cognitive load through a rating scale questionnaire, although it is difficult to clearly distinguish between intrinsic and extraneous cognitive loads.

The following further researches are recommended:

(i) A meta-analysis of sample size larger than the current one (22 studies) can be carried out in order to find out whether it will yield different results especially with moderator analyses. In addition, a consideration of other moderator variables (e.g. types of feedbacks, prompts or assessment of outcome measures) is crucial in order to study the effects of other study-level characteristics on the overall effect size.

(ii) To design a similar empirical study in order to investigate the effect of problem-solving and example-based learning on enhancing pre-service teachers' diagnostic competences through intervention, but rather with both immediate and delayed post testing to compare the effect of time on learning transfer.

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APPENDIX

Appendix A: Summary of studies included in the meta-analysis

Study	ES(g)	Var	Subjects			Moderators					
			EG (n_1)	CG (n_2)	Total sample size (N)	Domain	Exp. design	Prior Knowledge.	DI	EBL	PBS
Baghdady et al. (2014)	0.188	0.035	55	57	112	med	true	low	present	absent	absent
Bahreini et al. (2013)	1.125	0.062	35	38	73	med	quasi	high	absent	absent	present
Chamberland et al. (2011)	0.322	0.108	18	18	36	med	true	high	absent	absent	present
Chamberland et al. (2015)_1	0.52	0.11	19	17	54	med	true	low	absent	present	present
	0.644	0.115	18	17				low	absent	present	present
Chamberland et al. (2015)_2	0.609	0.118	18	16	53	med	true	low	absent	present	present
	0.804	0.119	19	16				low	absent	present	present
Eva et al. (2007)_1	0.506	0.13	15	15	60	med	true	low	present	present	present
	0.309	0.128	15	15				low	present	present	present
	-0.718	0.135	15	15				low	present	present	present
Eva et al. (2007)_2	0.188	0.081	24	24	48	med	true	low	present	present	present
Heitzmann (2014)	-0.475	0.052	39	38	152	med	true	high	absent	present	absent
	-0.609	0.055	37	38				high	absent	present	absent
	-0.114	0.052	38	38				high	absent	present	absent
Heitzmann et al. (2015)	0.176	0.081	25	23	98	med	true	high	absent	present	absent
	-0.157	0.081	25	23				high	absent	present	absent
	0.194	0.081	25	23				high	absent	present	absent
Heitzmann et al. (2018)	-0.292	0.074	26	27	108	t.edu	true	high	present	present	absent
	-0.461	0.071	29	27				high	present	present	absent
	0.13	0.073	26	27				high	present	present	absent
Ibiapina et al. (2014)	0.701	0.105	20	19	115	med	true	low	absent	absent	present
	0.614	0.106	19	19				low	absent	absent	present
	0.747	0.101	19	22				high	absent	absent	present
	0.76	0.111	16	22				high	absent	absent	present
Jarodzka et al. (2012)	0.014	0.096	20	20	60	med	true	low	absent	present	absent

	0.698	0.102	20	20				low	absent	present	absent
Klug et al. (2016)	1.317	0.146	15	17	47	t.edu	quasi	high	present	absent	present
	1.391	0.149	15	17				high	present	absent	present
Liaw et al. (2010)	0.798	0.139	13	17	30	med	quasi	low	absent	present	present
Mamede et al. (2012)	0.062	0.123	16	15	46	med	true	high	absent	absent	present
	-0.735	0.135	15	15				high	absent	absent	present
Mamede et al. (2014)	0.298	0.056	35	36	110	med	true	high	absent	absent	present
	0.959	0.058	39	36				high	absent	absent	present
Neistadt & Smith. (1997)	0.219	0.034	45	82	127	med	quasi	high	present	absent	present
Papa et al. (2007)	1.451	0.041	64	59	123	med	true	low	present	present	absent
Peixoto et al. (2017)	-0.14	0.099	20	19	39	med	true	low	absent	absent	present
Round (1999)	0.427	0.022	84	102	186	med	quasi	high	present	absent	present
Stark et al. (2011)_1	0.386	0.055	36	36	153	med	true	high	absent	present	absent
	-0.304	0.052	41	36				high	absent	present	absent
	-0.088	0.052	40	36				high	absent	present	absent
Stark et al. (2011) _2	0.601	0.057	30	29	124	med	true	high	absent	present	absent
	-0.259	0.052	32	29				high	absent	present	absent
	0.355	0.053	33	29				high	absent	present	absent

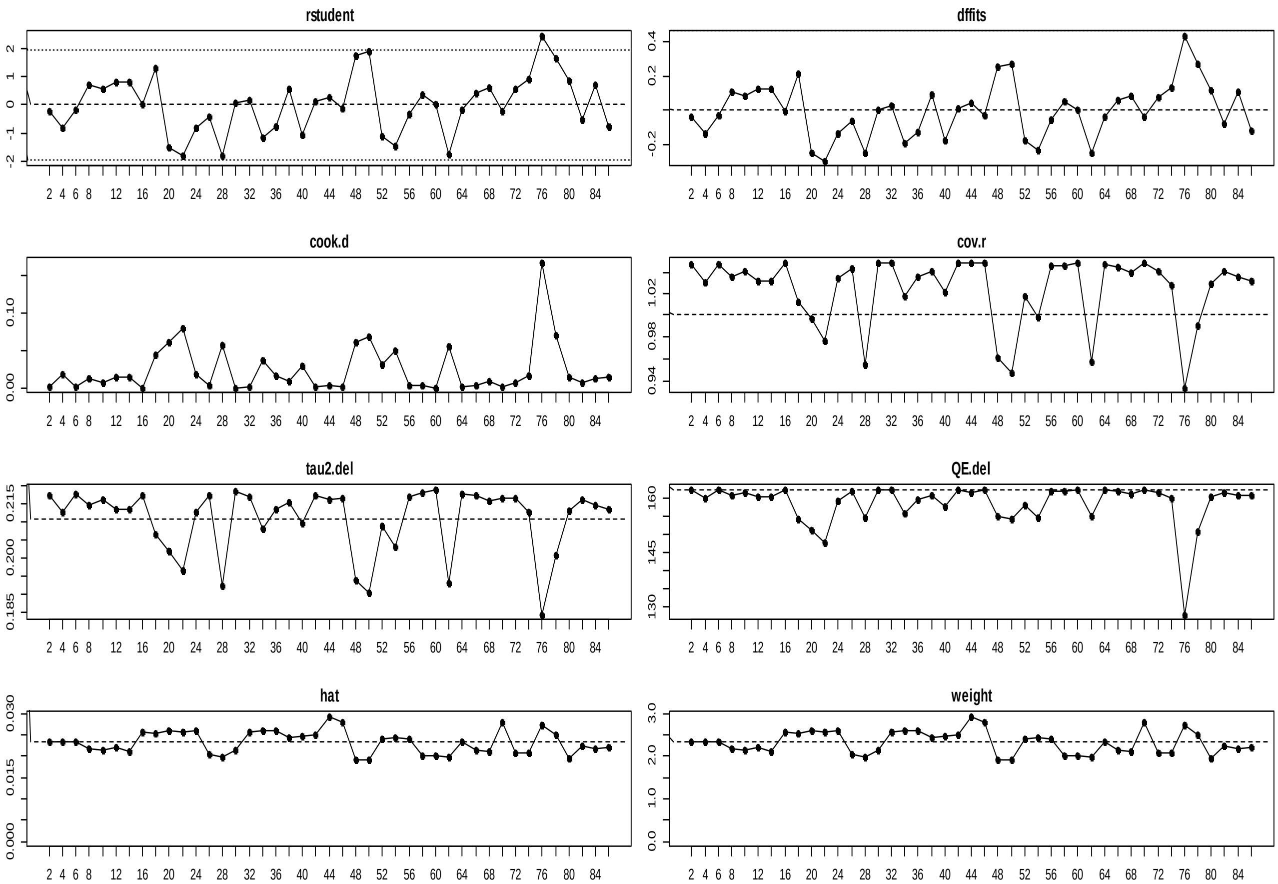
ES = effect size, g = Hedge's g, EG = Experimental group, CG = Control group, instr. = instructional
med = medical, t.edu = teacher education , DI = Diretct Instruction, EBL = Example-based Learning, PBS=Probelm Solving

Appendix B: General coding scheme for study characteristics/features

Study characteristic/feature	**Description**
Study ID.	Identification number for each primary study
Author(s)	Individual(s) who published a particular primary study
Year	Publication year of an article or manuscript write up
Total sample size	Total number of individuals who participated in the experiment
Type of participants (subjects)	Individuals who participated in the experiment e.g. medical students, pre-service teachers, nurses, etc.
Participants' mean age	Age of individuals who participated in the experiment
Year of study	The level of training program e.g. first year, second year, etc.
Participants' prior knowledge	Learners experiences or knowledge before they participate in the intervention
Instructional approach	Type of teaching or facilitation method applied during training or learning phase of an intervention e.g. Direct instruction, example-based learning, and problem-solving
Time-on-task (length of intervention)	Total time spend by individuals to perform tasks during learning or training phase of an intervention
Experimental design	Type of an experiment in which an intervention was conducted e.g. randomized experiment, quasi-experiment.
Domain	Specific field of study where the study was conducted e.g. medicine, teacher education.
Statistical data	Descriptive statistics (means, standard deviations, standard errors, or confidence intervals) for a particular outcome measure as it is reported in the results section of a primary study.
Sample size (Sub-groups)	Number of participants in each treatment or experimental group, and control condition or group, etc.
Effect size estimate (Cohen's d)	Measure of effect size estimate using descriptive statistics reported or requested from first authors in the results sections of primary studies.
Effect size estimate (Hedge's g)	Unbiased effect size estimate after conversion from Cohen's d using the given parameters (sample size for subgroups and degrees of freedoms) and a conversion factor (Borenstein et al., 2009).

Appendix C: A plot to identify influential studies

<u>Studentized residues, DFFITS values, Cook's distance and COVRATIO values for 43 effect sizes from 22 empirical studies</u>



Appendix D: Model of Diagnoser tool for first experimental condition

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Introduction:

This model of Diagnoser tool was prepared through imaging a situation whereby a pupil was interacting with computer program which produces questions via the internet. The questions were designed to elicit different **facets** of pupil's conception of ideas or thinking. When a pupil completes a set of questions the teacher can view facets diagnosed for each question.

How to identify pupil's misconception:

a) Understand the question/problem case given to a pupil.
b) Find out the correct answer/solution.
c) Compare between pupil's answer/solution and the correct answer/solution.
d) Judge whether pupils' answer/solution is correct or wrong.
e) Find out why a pupil has decided to write that answer/solution.
f) Determine pupil's misconception (false conception of idea or thinking).

Further instructions:

Please carefully study each question and alternative responses given for a pupil to choose the most correct answer. Then answer the following *guiding questions* so as to learn about pupils' misconceptions and how to diagnose them. You can use list of **Facets** provided on a separate sheets.
Note: *Pupils' answers or solutions are indicated by a dot or highlight in each question*.

Guiding questions:

i. *How do you judge about the pupil's answer in each question?*
ii. *If it is wrong which one do you think is the correct answer*?
iii. *State how a pupil has decided to choose that answer in each question?*
iv. *Identify and write down a particular misconception held by a pupil in case there is false conception of ideas.*
v. *Identify any other possible misconception held by a pupil who selects another alternative response in each question (see **alternative responses**).*

PART ONE: MECHANICS

Topic: Force and motion
Sub-topics: *Position and Distance, Change in Direction, Determining Speed, and Acceleration*

(a) **Position and Distance:** (*Set of questions as the pupil interacts with a computer program)*

Question: 1

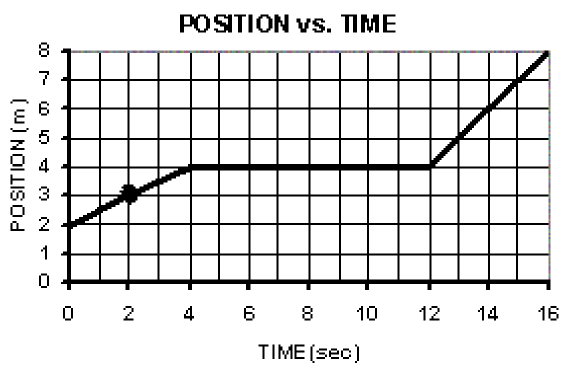


Fig.1

The motion of an object during a 16-second time period is graphed as shown in figure 1 above.

What is the object's position at the point indicated by a dot on the graph?

- 0.5 meters
- 1 meter
- 2 meters
- 3 meters

Question 2

How far has the object traveled from the beginning of the motion (t=0s) to the point indicated by the **dot** on the graph (t=2s) in figure 1 above?

- 0.5 meters
- 1 meter
- 2 meters
- 3 meters

Question: 3

Given the position and time data at into the table, how far did the object travel in the five seconds?

Position (meters)	Time (seconds)
5	0
10	1
10	2
10	3
20	4
30	5

○ 25 meters

○ 30 meters

○ 65 meters

○ 85 meters

(b) **Change of direction** (*Set of questions as a pupil interacts with computer program*)

Sub-topic: *Change in Direction*

Question: 1

The following graph in fig. 3 represents the motion of an object.

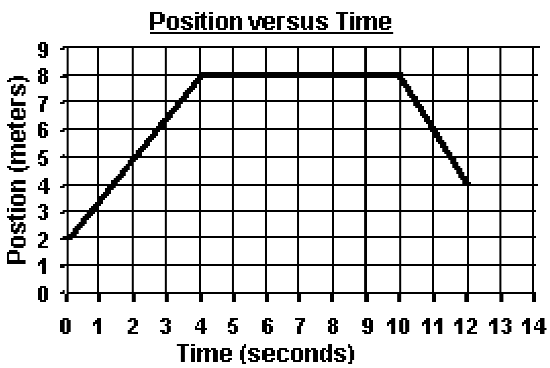


Fig.3

How far did the object travel during the 12 seconds?

○ 2 meters

○ 4 meters

○ 10 meters

○ 20 meters

Question: 2

What was the object's **change in position** during the 12 seconds on the graph in figure 3 above?

- 2 meters
- 4 meters
- 10 meters
- 20 meters

(c) **Determining Speed** (*Set of questions as a pupil interacts with computer program)*

Sub-topics: *Determining Speed*

Question: 1

A **position versus time** graph of the motion of a toy car is shown in figure 4 at the right bottom.

What is the speed of the car at t=2 seconds? Your answer must be a number

- 3.0 cm/s
- 4.0 cm/s
- 2.0 cm/s
- 6.0 cm/s

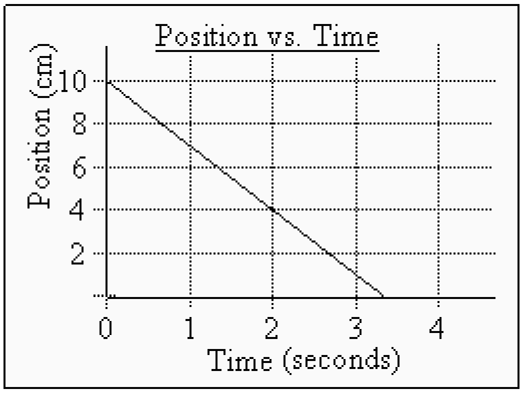


Fig.4

Question: 2

The **speed versus time** data for a racing car is graphed in fig. 5 at right. What is the speed of the car at t=2 minutes?

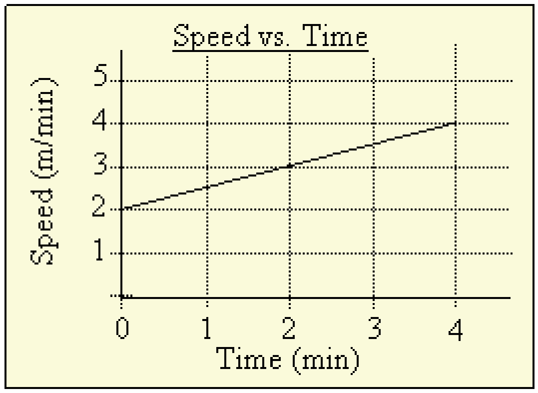


Fig.5

- 0.5 meters/minute
- 1.0 meter/minute
- 1.5 meters/minute
- 2.5 meters/minute
- 3.0 meters/minute

(d) **Acceleration** (*Set of questions as a pupil interacts with computer program)*

Sub-topic: *Acceleration*

Question: 1

Does the **speed versus time** graph below fig 6 represent an object that is accelerating?

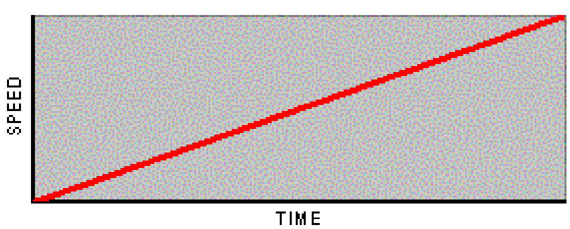


Fig. 6

Choose the answer and reasoning that best match your thinking.

- Yes; constant positive slope means increasing speed.
- No; constant positive slope means constant speed.
- Yes; the position is changing over time.
- No; when the speed = 0, the acceleration = 0.

Question: 2 A position versus time graph of Martha's motion is shown at Figure 7 below.

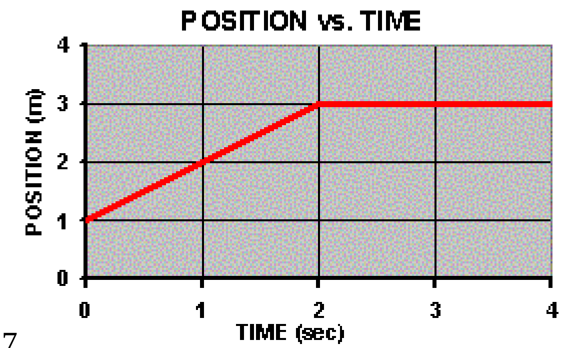


Fig.7

When is Martha accelerating?

- Around t = 1 sec
- Around t = 2 sec
- From t = 0 to t = 2 sec

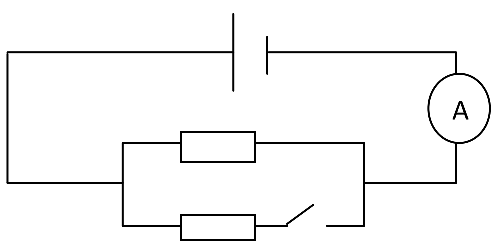
PART TWO: ELECTROMAGNETISM

Topic: Nature of forces
Sub-topics: *Current electricity*, *Electric forces, Electromagnetic forces*

(a) **Current electricity** (*Set of questions as a pupil interacts with computer program)*

Question: 1

Two resistors in this circuit are identical. The switch is open.
There is a reading on the ammeter.



The switch is then **closed**. (a) What happens to the reading on the ammeter?

- It gets bigger
- It stays the same
- It gets smaller
- It gets into zero

Question: 2

The two resistors in question 1 above are then arranged in series. The switch is open.
There is no reading on the ammeter.

The switch is then **closed**. (a) What happens to the reading on the ammeter?

- It gets bigger
- It stays the same
- It gets smaller
- It gets into zero

(b) **Electric forces**: (Set of questions as a pupil interacts with computer program)

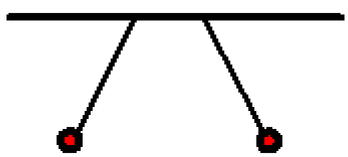
Question: 1

In the Physics demonstration, the professor rubbed a glass rod with a piece of silk and then brought the rod near some scraps of paper. Anna saw the paper jumps up off the table toward the rod.

Why did this happen?

- Static was put on the rod which makes things cling to it.
- The rod is now a magnet and polarizes the paper.
- The rod exerts a gravitational force on the paper.
- The rod is electrically charged and attracts the neutral paper.
- Electrons were created and put on the rod. Electrons attract paper.

Question: 2



The professor next brings out two identical metal balls hanging from threads as shown in the diagram on the right.

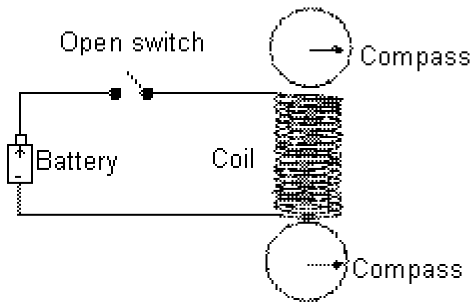
How would you explain this observation?

- Both balls are charged the same, either positively or negatively.
- One ball is positively charged; the other is negatively charged.
- One ball is charged; the other ball is neutral.
- The charged balls are now two N or two S poles of a magnet.

(c) **Electromagnetic forces** (*Set of questions as a pupil interacts with computer program)*

Question: 1

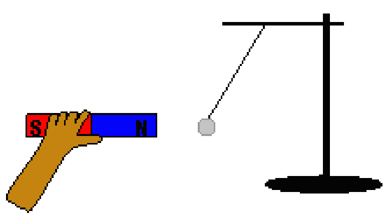
When the switch in the circuit at right is closed, the compass needle at the bottom of the coil points up. What direction does the compass needle at the top of the coil point when the switch is closed?

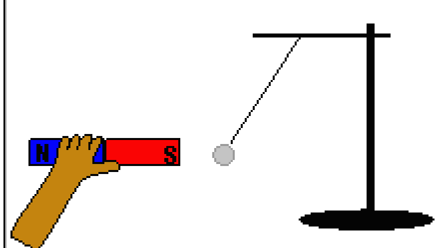
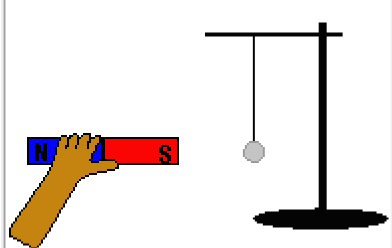
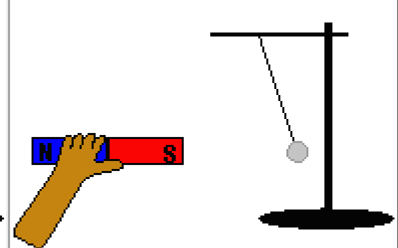


- Up
- Down
- The compass does not move.

Question: 2

A charged ball is hanging from a string. When a north pole of a magnet is brought near, the charged ball is attracted to the north pole.
Predict how the charged ball will behave when the south pole is brought near the charged ball.



		
Attract	**Do nothing**	**Repel**

- Attract
- Do nothing
- Repel

Appendix E: Model of Diagnoser tool for second experimental condition

Introduction:

This model of Diagnoser tool was prepared through imaging the situation whereby a pupil was interacting with computer program which produces questions via internet. The questions were designed to elicit different **facets** of pupil's conception of ideas or thinking. When a pupil completes a set of questions the teacher can view the facets diagnosed for each question.

How to identify pupil's misconception:

a) Understand the question/problem case given to a pupil.
b) Find out the correct answer/solution.
c) Compare between pupil's answer/solution and the correct answer/solution.
d) Judge whether pupils' answer/solution is correct or wrong.
e) Find out why a pupil has decided to write that answer/solution.
f) Determine pupil's misconception (false conception of idea or thinking).

Further instructions:

Please carefully study each question and its alternative **responses** given for a pupil to choose the correct answer. The information about whether it is **correct** or **incorrect** conception of idea, and a particular **misconception** is given. You are then required to explain the reason behind these false conceptions of ideas. **Note**: *Pupils answers/solutions are indicated by a dot or highlight in each question*.

PART ONE: MECHANICS

Topic: Force and motion
Sub-topics: *Position and Distance, Change in Direction, Determining Speed and Acceleration.*

(a) **Position and Distance** (*Set of questions as the pupil interacts with a computer program)*

Question: 1

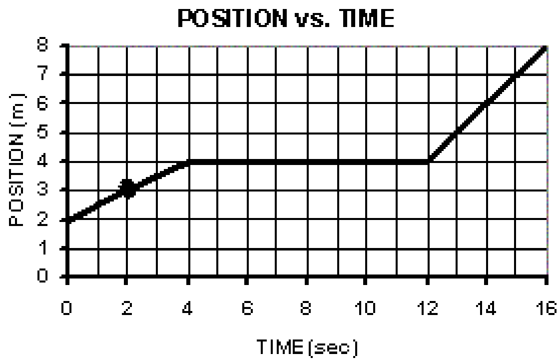


Fig.1

The motion of an object during a 16-second time period is graphed as shown in figure 1 above. What is the object's position at the point indicated by a dot on the graph?

[a] 0.5 meters

[b] 1 meter

[c] 2 meters

[d] 3 meters

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Pupil does not distinguish position from speed	
b	Wrong	Pupil does not distinguish between position and distance	
c	Unknown	-	-
d	Correct	-	-

Question 2

How far has the object traveled from the beginning of the motion (t=0s) to the point indicated by the **dot** on the graph (t=2s) above?

[a] 0.5 meters

[b] 1 meter

[c] 2 meter

[d] 3 meters

Key	Conception of idea	Misconception	Reason behind
a	Wrong	A pupil interprets a point on the position vs time graph to mean no motion	
b	Correct	-	-
c	Wrong	Distance is determined by reporting the peed	
e	Wrong	Distance travelled is determined by giving final position	

Question: 3

Given the position and time data at right, how far did the object travel in the five seconds?

Position (meters)	Time (seconds)
5	0
10	1
10	2
10	3
20	4
30	5

[a] 25 meters

[b] 30 meters

[c] 65 meters

85 meters

[d]

Key	Conception of idea	Misconception	Reason behind
a	Correct	-	-
b	Wrong	Distance travelled is determined by giving final position.	
c	Wrong	Distance is determined by adding two or more positions during the motion.	
d	Unknown	-	-

(b) **Change of direction** (*Set of questions as the pupil interacts with a computer program*)

Question: 1

The following graph in figure 3 below represents the motion of an object.

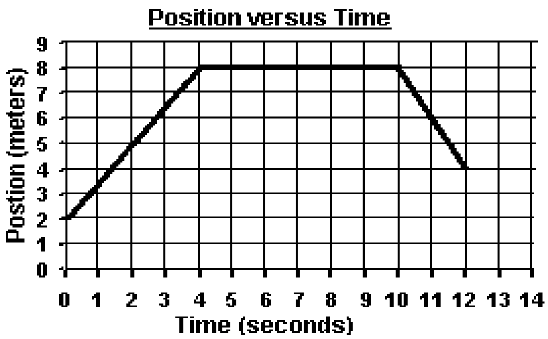


Fig.3

How far did the object travel during the 12 seconds?

[a] 2 meters

[b] 4 meters

[c] 10 meters

[d] 20 meters

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Pupil does not distinguish distance and change in position	
b	Wrong	Pupil does not distinguish the ideas of change in position /distance.	
c	Correct	-	-
d	Wrong	Pupil determines distance by adding two or more positions	

Question: 2

What was the object's **change in position** during the 12 seconds on the graph in Qn. 1 above?

[a] 2 meters

[b] 4 meters

[c] 10 meters

[d] 20 meters

Key	Conception of idea	Misconception	Reason behind
a	Correct	-	
b	Wrong	Change in position is determined by giving position only	
c	Wrong	Change in position is determined by distance travelled even in situations where the resultant is not the same	
d	Wrong	Distance is determined by adding two or more positions during motion	

(c) **Determining Speed** (*Set of questions as a pupil interacts with computer program)*

Question 1

A **position versus time** graph of the motion of a toy car is shown at figure 4 in the right.

What is the speed of the car at t=2 seconds? Your answer must be a number.

[a] 3.0 cm/s

[b] 4.0 cm/s

[c] 0 cm/s

[d] 6.0 cm/s

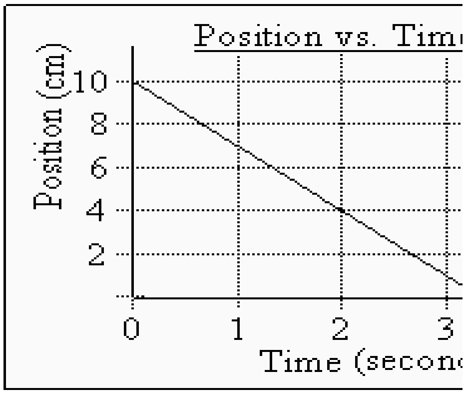


Fig. 4

	Key	Conception of idea	Misconception	Reason behind
	A	Correct	-	
	B	Wrong	Pupil incorrectly report another quantity or rate	
	C	Wrong	Same	
	D	Wrong	Same	

Question 2

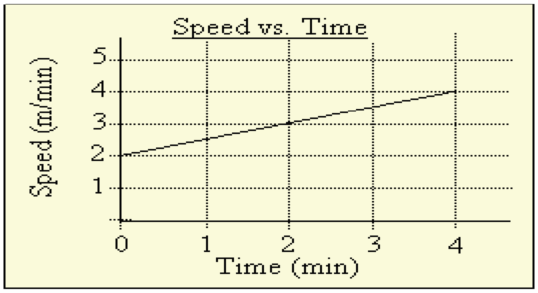


Fig.5

The **speed versus time** data for a racing car is graphed in figure 5 above.

What is the speed of the car at t=2 minutes?

[a] 0.5 meters/minute
[b] 1.0 meter/minute
[c] 1.5 meters/minute
[e] 3.0 meters/minute

Key	**Conception of idea**	**Misconception**	**Reason behind**
a	Wrong	divides the change in speed by the final time or change in time	
b	Wrong	A pupil reports the change in speed	
c	Wrong	A pupil divides the speed by the final time or change in time.	
D	Correct	-	

(d) **Acceleration** (*Set of questions as the pupil interacts with a computer program)*

Question: 1

Does the **speed versus time** graph below represent an object that is accelerating?

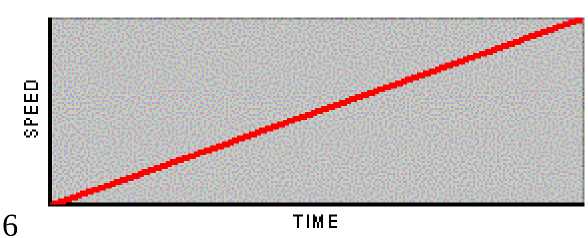


Fig. 6

Choose the answer and reasoning that best match your thinking.

[a] Yes; constant positive slope means increasing speed.

[b] No; constant positive slope means constant speed.

[c] Yes; the position is changing over time.

[d] No; when the speed = 0, the acceleration = 0.

Key	Conception of idea	Misconception	Reason behind
a	Correct	-	-
b	Wrong	interprets sloping up on a speed graph to mean the object is moving with constant speed away from the origin	
c	Wrong	Pupil determines the acceleration by noting the change in position	
d	Wrong	Pupil thinks that if an object has zero speed, even for an instant, it also has zero acceleration.	

Question: 2 A position versus time graph of Martha's motion is shown at Figure 7 below.

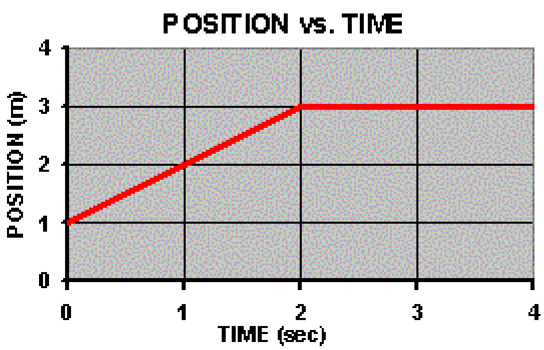


Fig.7

When is Martha accelerating?

[a] Around t = 1 sec

[b] Around t = 2 sec

[c] From t = 0 to t = 2 sec

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Pupil concludes that if an object has a speed, it must be accelerating.	
b	Correct	-	
c	Wrong	A pupil interprets sloping up (or down) on a position graph to mean the object is speeding up (or slowing down).	

PART TWO: ELECTROMAGNETISM

Topic: Nature of forces
Sub-topics: *Current electricity***,** *Electric forces, Electromagnetic forces*

(a) **Current electricity** (*Set of questions as a pupil interacts with computer program)*

Question: 1

Two resistors in this circuit are identical. The switch is open.

There is a reading on the ammeter.

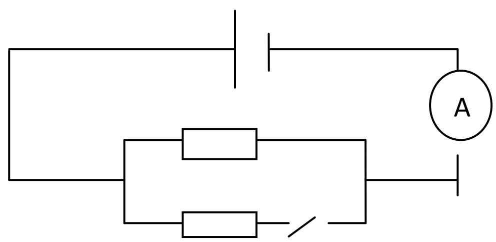


Figure 8.

The switch is then **closed**. (a) What happens to the reading on the ammeter?

- It gets bigger
- It stays the same
- It gets smaller
- It gets into zero

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Resistors in parallel have the same combined resistance	Pupil does not understand the idea of resistors in parallel
b	Correct	-	-
c	Wrong	Resistors in parallel have larger combined resistance	Pupil does not understand the idea of resistors in parallel
d	Wrong	-	-

Question 2:

The two resistors in question 1 above are then arranged in series. The switch is open. There is no reading on the ammeter.

The switch is then **closed**. (a) What happens to the reading on the ammeter?

a) ○ It gets bigger

b) ○ It stays the same

c) ○ It reduces to half

d) ○ It gets into zero

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Same resistors in series have less resistance	
b	Wrong	Resistor in series have same combined effect as in parallel	
c	Correct	-	
d	Unk	Unknown	

(b) Electric force (Set of questions as a pupil interacts with a computer)

Question: 1

In the Physics demonstration, the professor rubbed a glass rod with a piece of silk and then brought the rod near some scraps of paper. Anna saw the paper jumps up off the table towards the rod. Why did this happen?

a) Static was put on the rod which makes things cling to it.

b) The rod is now a magnet and polarizes the paper.

c) The rod exerts a gravitational force on the paper.

d) The rod is electrically charged and attracts the neutral paper.

e) Electrons were created and put on the road. Electrons attract paper.

Key	Conception of idea	Misconception	Reason behind
a	Wrong	Friction or 'static' is a substance that flows onto objects and makes them charged	
b	Wrong	Charging an object is just the same as making a magnet.	
c	Wrong	The attraction between a charged object and other objects is the gravitational force.	
d	Correct		

e	Wrong	Electrons are created by friction	

Question: 2

The professor next brings out two identical metal balls hanging from threads as shown in the diagram on the right. How would you explain this observation?

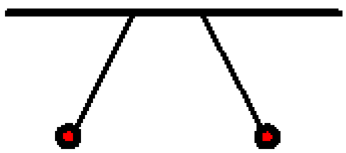


Fig. 9

a) Both balls are charged the same, either positively or negatively.
b) One ball is positively charged; the other is negatively charged.
c) One ball is charged; the other ball is neutral.
d) The charged balls are now two N or two S poles of a magnet.

Key	Conception of idea	Misconception	Reason
a	Wrong		
b	Wrong	Pupil does not understand the evidence for the existence of two different kinds of charge as well as a neutral condition	
c	Wrong	Same	
d	Wrong	Charged objects are just magnetic poles.	
e	Correct	-	

(c) Electromagnetic forces (*Set of questions as a pupil interacts with computer program)*

Question: 1

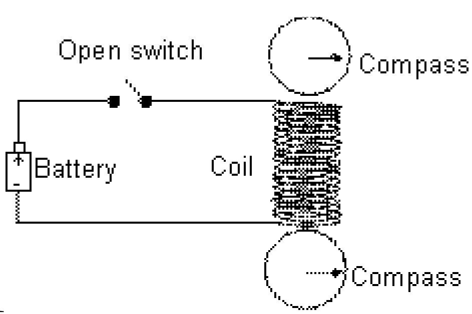


Fig.11

a) Up

b) Down

c) The compass does not move.

Key	Conception of idea	Misconception	Reason
a	Correct	-	
b	Wrong	A pupil thinks the compass will point towards the wire when it has a current	
c	Wrong	A pupil believes that a magnet does not interact with a current-carrying wire.	

Question: 2

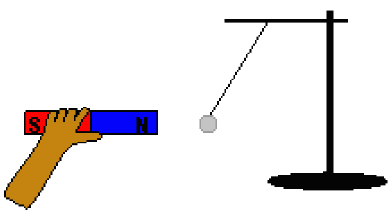


Fig.12

a) Attract

b) Do nothing

c) Repel

Key	Conception of idea	Misconception	Reason
a	Correct	-	
b	Wrong	The student confuses magnetic and electric effects	
c	Wrong	The pupil thinks that magnets are objects with permanent amounts of electric charge on their ends.	

Appendix F: First Questionnaire: A multiple choice knowledge test

Introduction:

Dear participants, I would like to ask you to complete this questionnaire in form of an objective knowledge test. Your contributions has great values towards my research work about pre-service teachers' diagnostic competence in physics misconceptions. Therefore, I kindly ask you to complete the questionnaire by answering all the questions which follow after each pupil's question or problem case scenario. Please carefully read instructions in each section before you proceed. Thank you.

Important information:

Date: ………/………/2017 Group number: …………………….
Your number …………………….. Campus: ……………………………

Personal information:

Degree program: BSc. Ed. ( ) BEd. Sc. ( ) Year of study: ………
Age: ……… (Years) Sex: ……..M/F

Section A: Single choice items

Instruction: A pupil was interacting with a computer program which displays sets of physics questions as shown in the boxes below. Carefully study each pupil's question and then answer the following questions by choosing the most correct alternative response. **Note:** *Pupil's answers are indicated by a dark dot or highlight***.**

Pupil's question: 1

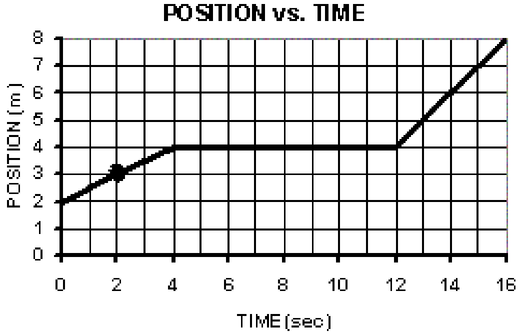


Fig.1

The motion of an object during a 16-second time period is graphed as shown in figure 1 above.

How far did the object travel in the 16 seconds?

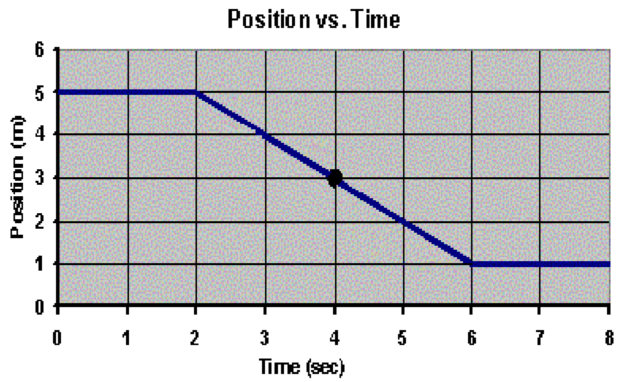
- ○ 6 meters
- ◉ 8 meters
- ○ 10 meters
- ○ 16 meters

Questions:

1. How do you judge this answer which is given by a pupil?
   (a) correct conception of idea
   (b) wrong conception of idea
   (c) partially correct conception of idea
   (d) partially wrong conception of idea [ ]
2. How do you think a pupil has decided to write this answer? The pupil has …
   (a) just used a distance formula
   (b) just read the initial position
   (c) read object's final position
   (d) subtracted initial position from final position [ ]
3. Which one do you think is the correct answer from this pupil's question?
   (a) 6 meters
   (b) 8 meters
   (c) 10 meters
   (d) 16 meters [ ]
4. What is the pupil's misconception in this problem?
   (a) The pupil incorrectly identifies initial position as zero

(b) The pupil incorrectly identifies final position as 8 meters
(c) The pupil incorrectly identifies initial position as 2 meters
(d) There is no misconception in this question [ ]

Pupil's question : 2



Figue 2.

Figure 2 above shows another graph of an object moving during 8-minute interval.

How far did the object travel during 8 seconds?

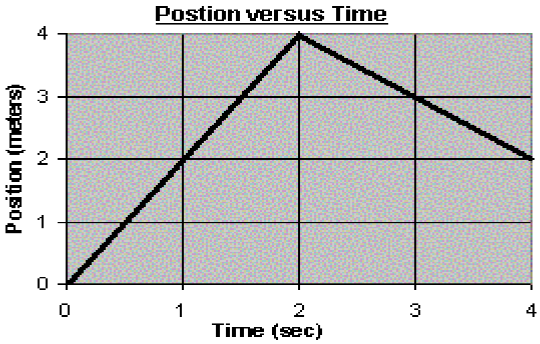
- 1 meter
- 3 meters
- 4 meters
- 8 meters

Questions:

5. How do you judge this answer which is given by a pupil?
   (e) correct conception of idea
   (f) wrong conception of idea
   (g) partially correct conception of idea
   (h) partially wrong conception of idea [ ]
6. How do you think a pupil has decided to write this answer?
   (a) He has read the initial position of object
   (b) He has read the final position of object
   (c) He has added the initial and final positions
   (d) He subtracted initial position from final position [ ]
7. Which one do you think is the correct answer in this question?
   (a) 1 meter
   (b) 3 meter
   (c) 4 meters
   (d) 8 meters [ ]
8. What is the pupil's misconception in this question?

(a) The distance is determined by giving final position
(b) The distance is determined by reporting the speed
(c) The distance is determined by adding two positions
(d) There is no misconception in this problem [ ]

Pupil's question : 3



An object's motion is represented on the position versus time graph at right.
How far did the object travel during 4th second?

○ 0.5 meters

◉ 2 meters

○ 4 meters

○ 6 meters

Questions:

9. How do you judge this answer which is given by a pupil?
   (a) correct conception of idea
   (b) wrong conception of idea
   (c) partially correct conception of idea
   (d) partially wrong conception of idea [ ]
10. How do you think a pupil has decided to write this answer? The pupil has …
   (a) added initial position and final position
   (b) added the initial, middle, and final positions
   (c) viewed object's final position
   (d) subtracted final position from initial position [ ]
11. Which one is the correct answer in this question?
   (a) 0.5 meters
   (b) 2 meters
   (c) 4 meters
   (d) 6 meters [ ]
12. What is the pupil's misconception in this case?
   (a) The distance travelled is always determined by giving final position
   (b) The distance travelled is always determined by reporting the speed
   (c) The distance travelled is always determined by change in positions

(d) There is no misconception in this question [ ]

Pupil's question: 4

The following table below shows the positions and time data for a car's motion.

POSITION (m)	TIME (sec)
4	0
6	1
8	2
11	3
16	4

What is the cart's average speed during the 4th second motion?

- ○ 3.0 m/sec
- ○ 3.5 m/sec
- ◉ 4.0 m/sec
- ○ 5.0 m/sec

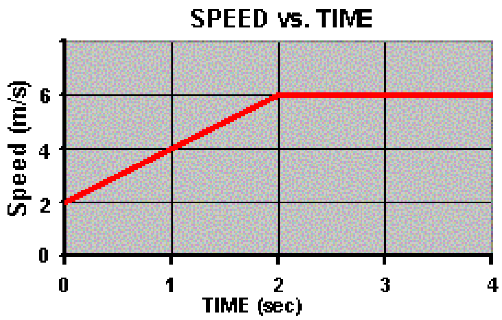
Questions:

13. How do you judge this answer which is given by a pupil?
    (a) correct conception of idea
    (b) wrong conception of idea
    (c) partially correct conception of idea
    (d) partially wrong conception of idea [ ]
14. How did the pupil compute average speed in this problem?
    (a) By finding sum of initial and final position
    (b) By computing difference between initial and final time
    (c) Dividing final position when initial position was not zero [ ]
    (d) By finding difference between final and initial position
15. Which one is the correct answer in this question?
    (a) 3.0 m/s
    (b) 3.5 m/s
    (c) 4.0 m/s [ ]
    (d) 5.0 m/s
16. What is the pupil's misconception in this case?
    The pupil determines average speed by dividing distance travelled to the time when…
    (a) Initial potion was zero
    (b) initial time was not zero

(c) Initial position was not zero [ ]

(d) Final time was zero

Pupil's question: 5



*The figure above shows a **speed versus time** graph of a bicycle. When was bicycle accelerating?*

- From t = 0 to t = 2 seconds
- At t = 2 seconds
- From t = 2 to t = 4 seconds
- Never at all points

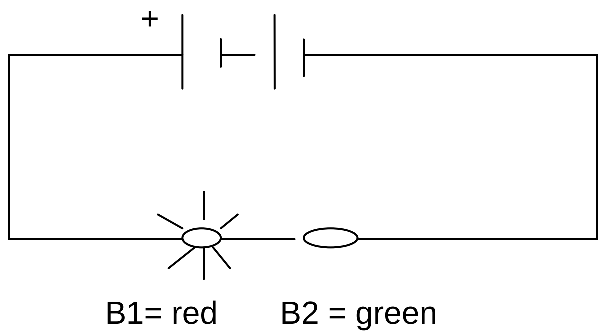
Questions:

17. How do you judge this answer which is given by a pupil?
    (a) correct conception of idea
    (b) wrong conception of idea
    (c) partially correct conception of idea
    (d) partially wrong conception of idea [ ]
18. How do you think a pupil has decided to write this answer? The pupil has observed …
    (a) the position where an object changes its motion
    (b) line segment for increasing speed
    (c) middle positions where the line changed its slope [ ]
    (d) line segment at constant speed
19. Which one is the correct answer in this pupil's problem?
    (a) from t = 0 to t =2 seconds
    (b) at t = 2 seconds
    (c) From t = 2 to t = 4 seconds [ ]
    (d) Never at all
20. What is the pupil's misconception in this case?
    (a) The pupil interprets acceleration as high speed
    (b) The pupil interprets change of motion as acceleration

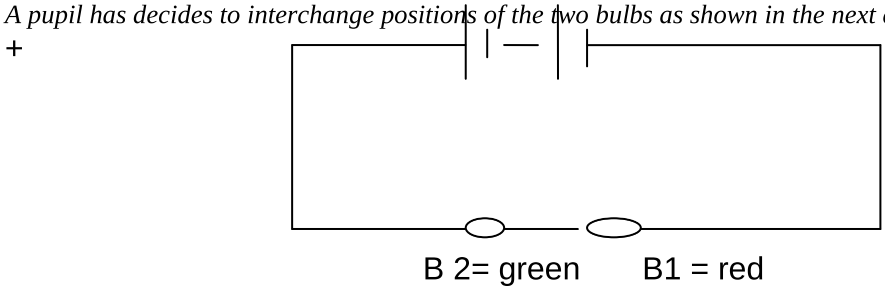
(c) The pupil observes flat line segment as uniform acceleration
(d) There is no misconception in this question [ ]

Pupil's question : 6

*In this circuit, the red bulb is **bright** and the green bulb is **dim**.*



A pupil has decides to interchange positions of the two bulbs as shown in the next diagram. (see next diagram.



How bright will both bulbs be then?

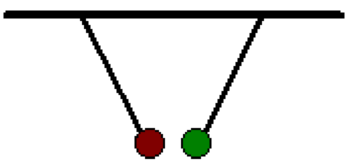
- Same as before (the red bulb is bright).
- They change over (the green bulb is bright).
- Both bulbs are now bright.
- Both bulbs are now dim.

Questions:

21. How do you judge this answer which is given by a pupil?
    (a) correct conception of idea
    (b) wrong conception of idea
    (c) partially correct conception of idea
    (d) partially wrong conception of idea [ ]

22. How has the pupil decided to write the answer in this question?
    (a) She thinks that bulb 1(red) is always dim
    (b) She thinks that bulb 2(green) is always bright
    (c) She thinks that electric current depends a bulb position
    (d) She thinks that electric current depends on bulb color [ ]
23. Which one is the correct answer in this pupil's question?
    (a) Same as before (the red bulb is bright).
    (b) They change over (the green bulb is bright).
    (c) Both bulbs are now bright
    (d) Both bulbs are now dim [ ]
24. What is the pupil's misconception in this case? …
    (a) The pupil thinks that bulbs have equal voltage in series circuit
    (b) The pupil thinks that bulbs have same resistance in series circuit
    (c) The bulbs thinks that bulbs have same resistance in parallel circuit [ ]
    (d) There is no misconception in this problem

Pupil's question: 7



Amina attended a lecture where several Physics demonstrations were shown by a professor. The professor first brought out two small balls, one metal and one plastic, hanging from threads as shown in the diagram at above.

Which statement below best explains this situation?

- (•) At least one of the objects is electrically charged.
- ( ) Only the metal ball is charged because plastic is an insulator.
- ( ) The two balls must be charged oppositely because they attract.
- ( ) The two balls are now north and south poles of a magnet.

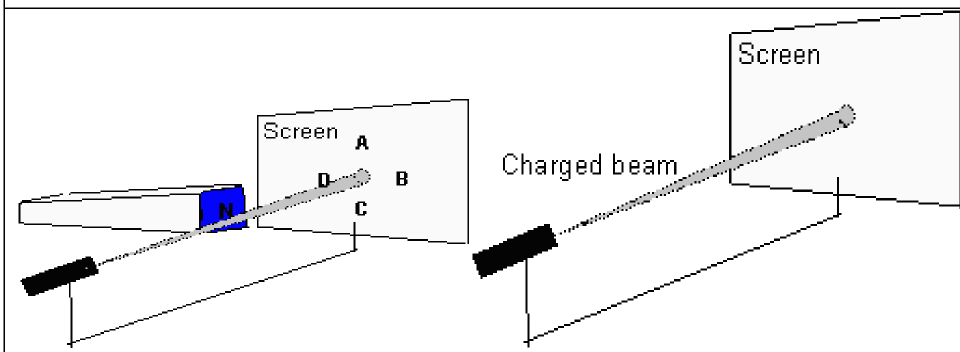
Questions:

25. How do you judge this answer which is given by a pupil?

    (a) correct conception of idea
    (b) wrong conception of idea
    (c) partially correct conception of idea
    (d) partially wrong conception of idea [ ]

26. How has Amina decided to write her answer in this question?
   (a) She thinks that only metals can be charged
   (b) She thinks considers that only plastic can be charged
   (c) She thinks that both metal and plastic can be charged [ ]
   (d) She is just guessing the answer
27. What is the correct answer in this pupil's question?
   (a) At least one of the objects is electrically charged.
   (b) Only the metal ball is charged because plastic is an insulator
   (c) The two balls must be charged oppositely because they attract.
   (d) The two balls are made into opposite poles of a magnet. [ ]
28. What is the misconception held by Amina in this case?
   (a) She thinks that unlike charges attract one another
   (b) She thinks that metals always attract plastics
   (c) She thinks that all metals are magnets [ ]
   (d) Amina has no any misconception in this question

Pupil's question: 8



In the experiment, as shown above on left, a beam of positively charged particles bombard a screen.

When the north pole of a strong magnet is placed to the left of the beam, as shown above on right, what happens to the beam? **Note: The pupil's answer is indicated below by a dark dot or highlight.**

- ○ Deflects toward B
- ○ Deflects toward C
- ○ Deflects toward D
- ◉ The beam does not deflect

Questions:

29. How do you judge this answer which is given by a pupil?
    (a) correct conception of idea
    (e) wrong conception of idea
    (b) partially correct conception of idea
    (c) partially wrong conception of idea [ ]
30. How has the pupil decided to write her answer in this question?
    (a) The pupil has applied Fleming's right hand rule correctly
    (b) The pupil ha applied Fleming's left hand rule correctly
    (c) The pupil has incorrectly applied Fleming's left hand rule
    (d) The pupil has applied both Fleming's left hand right rules [ ]

31. What is the correct answer in this problem from your knowledge?
    (a) The beam deflects towards B
    (b) The beam deflects towards C
    (c) The beam deflects towards D [ ]
    (d) There is no effect on the beam
32. What is the pupil's misconception in this case? The pupil thinks that …
    (a) unlike charges repel
    (b) like charges attract
    (c) charges always attract magnets [ ]
    (d) magnet does not interact with electric current

Section B: Short answers items

Instruction: Answer all the following questions in this section by writing down the letter of the correct answer in the space provided.

33. List down the steps which you would carry out in order to determine a pupil's false conception of ideas or misconceptions from a particular Physics topic. The steps are listed into the box in random order. Choose among alternatives and write down the letters of the correct steps beginning with the first step in the space provided.

(A) Find out the solution/correct answer. (B) Identify pupil's misconception. (C) Compare between the correct answer and pupil's answer. (D) Understand the problem/question (E) Judge whether the pupil's solution/answer is correct or incorrect (F) Find out why a pupil has decided to write that answer

i. ………………………..
ii. ………………………..
iii. ………………………..
iv. ………………………..
v. ………………………...
vi. …………………………

34. Suppose you have already determined a particular pupil's Physics misconception, what next steps would you carry out as a Physics teacher in order to correct/clear up this false conception? From the alternatives given in the box below write down the letter steps in correct sequence.

(A) Identify the intuitive ideas of the pupil. (B) Show up to a pupil the required scientifically accurate learning idea. (C) Identify reasons behind pupil's answer. (D) Identify other possible intuitive ideas

i. ……………..
ii. ……………..
iii. ……………..
iv. ……………..

35. In the previous Physics lesson about force and motion in mechanics you have noticed that some pupils incorrectly identified initial position of an object as always zero. Then, you decide to clear up this misconception by performing a short Physics activity. How best would you use the following strategies to correct pupils' misconceptions about object's initial position? Arrange the following instructional steps provided in the box below in correct order.

A: Ask them to compare their answers. B: Ask one pupil to walk from zero mark up to the end. C: Use a meter rule to measure a path along the ground about 6m long. D: Ask other two pupils to walk starting from 1m, 2m and 3m marks respectively up to the end. E: Ask each pupil to calculate distance travelled by subtracting his or her initial position from the final position.

i. ……………
ii. ……………
iii. ……………
iv. ……………
v. ……………

Appendix G: Second Questionnaire: A rating scale for measuring cognitive load

Introduction:

Dear participants I would like to ask you to complete the following questionnaire which intends to find out your experience in the training that *is taking/has already taken* part. Your contribution is very important towards my research project. Therefore I kindly ask you to read each item carefully and respond to each question on the scale presented form '0' indicating Not at all to '10' indicates completely the case. *Put a tick (√) against the number you think fits to what you have just experienced.*

Important information:

Date: ……………………………… Group number: …………………….
Your Number: ……………………. Campus: ……………………………

Personal information: *Please put a tick* (√).

Degree program: BSc. Ed. ( ) BEd. Sc. ( ) Year of study: 1st ( ) 2nd ( ) 3rd ( )
Age: ……… (Years) Sex: Male ( ) Female ( )

0 = Not at all 10 = completely the case

S/N	Item	Response										
		0	1	2	3	4	5	6	7	8	9	10
1	The content of this activity was very complex.											
2	The problem/s covered in this activity was/were very complex.											
3	In this activity, very complex terms were mentioned.											
4	I invested a very high mental effort in the complexity of this activity.											
5	The explanations and instructions in this activity were very unclear.											
6	The explanations and instructions in this activity were full of unclear language.											
7	The explanations and instructions in this activity were, in terms of learning, very ineffective.											
8	I invested a very high mental effort in unclear and ineffective explanations and instructions in this activity.											
9	This activity really enhanced my understanding of the content that was covered.											
10	This activity really enhanced my understanding of the problem/s that was/were covered.											
11	This activity really enhanced my knowledge of the terms that were mentioned.											
12	This activity really enhanced my knowledge and understanding of how to deal with the problem/s covered											
13	I invested a very high mental effort during this activity in enhancing my knowledge and understanding											