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Interest, Motivation, and Learning Strategy Use during Physics Learning

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Erklärung

Hiermit erkläre ich, dass diese Dissertation meine eigene Arbeit ist, die unter der Betreuung von erstellt wurde Prof. Dr. Ulrich Schiefele und Assoc. Prof. Joseph Ssenyonga. Alle verwendeten indirekten und direkten Quellen wurden als Quellenangaben angegeben. Mir ist bekannt, dass diese Dissertation auf Benutzung unerlaubter Hilfsmittel geprüft werden kann. Diese Dissertation ist weder in der aktuellen noch in einer anderen Fassung in einem anderen Prüfungsverfahren angenommen oder abgelehnt worden, noch habe ich mich zur Prüfung an einer anderen Hochschule beworben.

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Datum, Ort

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Diana Kwarikunda

Declaration

I hereby declare that this dissertation is my own work, developed under the supervision of Prof. Dr. Ulrich Schiefele and Assoc. Prof. Joseph Ssenyonga. All indirect and direct sources used are acknowledged as references. I am aware that this dissertation can be examined for use of unauthorised aid. This dissertation has not been accepted or rejected in the current or in a different version in any other examination procedures, nor have I applied for of this dissertation for examination at any other university.

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Date, Place

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Diana Kwarikunda

Dedication

To my children: Mary Goreth Nalubega, Mellissa Gabriella Nabachwa, and Maurice Anthony Lubega.

Acknowledgement

I would like to thank the Almighty for the gift of life, patience and perseverance He has given to me. Praise be to Him, for His goodness has never failed me. The completion of this dissertation would not have been possible without assistance and support from different people and organisations.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Present Study

With the growing need for scientific innovations in technology to solve various health, environmental, and other world challenges, there are no doubts, countries worldwide will continue promoting science education in their schools' curricular. One of the fundamental science subjects is being promoted besides mathematics is physics. Studying physics generates the fundamental knowledge needed for the future advancements in environmental and health technologies. We form a better understanding of the natural phenomena around us through knowledge of physics (Saleh, 2014; Sidin, 2003). Additionally, through studying physics, countries prepare a workforce with high reasoning and critical thinking skills necessary to front ideas in scientific advances, discoveries and technology that will continue to drive the economic engines of the world (Angell et al., 2004). More so, a tremendous amount of instrumentation and techniques for medical and daily applications that result into an improvement in the quality of life are invented using basic knowledge of physics. Extended applications of physics exist in fields of energy, transportation, space, communications, medicine, and environmental science.

To promote science education, many countries continue to allocate vast amounts of funding to facilitate research, buying of instructional materials, construction of state of art laboratories, and payment of teacher's salaries, among other activities. Despite these investments, there has been a global outcry over the poor achievement of students in science subjects (Christidou, 2011; Eccles & Wigfield, 2002; Keller et al., 2017) and especially physics (Barmby et al., 2008; Oon & Subramaniam, 2011) at secondary school level. Consequently, the number of students willing to offer physics at advanced and tertiary level continues to lower in some countries (Osborne et al., 2003). For instance, in United States of America (USA) and United

Kingdom (U.K.), studies (e.g., Barmby et al., 2008; Osborne et al., 2003; Potvin & Hasni, 2014) indicate that there has been a decline in number of students choosing to pursue physics-oriented courses after high school. Additionally, in the U.K., there was a 41% drop in number of students taking physics in their Advanced level combination (Osborne et al., 2003). This trend in physics achievement has not been different with other developed countries like China, South Korea, Canada, and Finland (Barmby et al., 2008).

Developing countries too are struggling with the poor achievement in science, especially physics, consequently resulting into a decrease in number of students willing to offer physics at advanced and tertiary level, threatening the future supply of a physics-oriented workforce. In Kenyan high school students, Amunga et al. (2011) and colleagues noted a decreasing trend in students' physics achievement and enrolment over years. Similarly, Uganda has had a haunting share of this experience over the previous years. For the past decade, statistics from Uganda National Examinations Board (UNEB) indicate that of all the science subjects, physics has been the worst performed subject national wide at lower secondary school. For instance, in 2015 of the 303,237 students who sat for the physics national exam, only 15.5% passed with credits and distinctions while in 2016, of the 323,276 students, only 9.7% passed with credits and distinction (UNEB, 2015, 2016). It is noted that this poor achievement does not occur only in the final exam but rather mostly through out lower secondary school. For example, on comparing the achievement in various grades, a significant decrease in learners' achievement is noticed to begin from the 9^{th} grade and continues to the 11^{th} grade (Amunga et al., 2011; Kahle, 1994; Kwarikunda et al., 2020). Additionally, the number of students willing to offer physics post lower secondary in Uganda is alarming. For instance, of the 15.5% of the students who passed physics at Lower secondary in 2015, only 6.9% registered for physics at Advanced level (UNEB 2016,2018). In his research on science motivation, Muwonge et al. (2020) noted a low enrolment of students in classes that offer physics as a major or minor subject as compared to other science subjects.

More so, there are discrepancies in physics achievement across gender. Worldwide, it has been noted that boys show greater science achievement than girls (Chang & Yuan, 2008;

González et al., 2017). An assessment by National Assessment of Educational Progress (NAEP) in 2005 revealed that male students outperformed their female counterparts in science achievement in grades 4, 8 and 12 in USA. In most cases by 11^{th} grade, the areas of largest male advantage were physics and mathematics (Kahle, 1994; Lee & Burkam, 1996). Similarly in Uganda, male students out perform female students in most science subjects (UNEB, 2017). However, the gender gap in Physics is wider as compared to other subjects. For instance, between 2012 to 2018, the number of male students who obtained at least a credit in Physics triples that of females (9.8% to 12.3 %, UNEB, 2017)

Similarly, gender differences not only exist in achievement patterns but also further manifest in the gender representation in physics related fields. As noted in Jacobs (2005) and in the Organisation for Economic Cooperation and Development report OECD, 2010, the female representation in the physics-oriented career fields is still low, with many African countries have the lowest number of women enrolled in physics-based training and professions among the world (Amunga et al., 2011; Frazier-Kouassi, 1999). For instance, the share of females in physics-oriented careers was below 20% in Botswana, Gambia, Guinea, Nigeria, Ghana, and Swaziland (United Nations Educational, Scientific and Cultural Organization; UNESCO, 2008). In a Kenyan county, no single girl registered for physics (Amunga et al., 2011). If the physics achievement and gender gap challenges are not addressed earlier, a shortage of physics-oriented yet gender-balanced workforce and consequently a slowed technological development trend for most developing countries (Ipar, 2011) especially Uganda will occur. Thus, it is timely to investigate a range of factors affecting the physics learning process. Results from such an investigation would provide a basis for efficient and effective interventions to address some of the reasons for poor physics achievement.

The learning process is a result of interaction of ones' learning behaviours, personal and environmental factors (Bandura, 1986; Pintrich, 2000; Zimmerman, 2000). Various research (e.g., Barmby et al., 2008; Bouckenooghe et al., 2016; Kind et al., 2007; Osborne et al., 2003; Potvin & Hasni, 2014; Schunk et al., 2008; Sjøberg & Schreiner, 2010) have been conducted to explore the interactions of these factors and learning outcomes. Evidence from some of these studies indicate that achievement in science in general is influenced by students' attitudes (Barmby et al., 2008; Osborne et al., 2003) , interest (Krapp & Prenzel, 2011; Schiefele, 1999, 2009), motivation (Eccles & Wigfield, 2002; Keller et al., 2017; OECD, 2010), and use of learning strategies (Sjøberg & Schreiner, 2010). Initiative-taking students are usually interested in classroom activities (Ardura & Pérez-Bitrián, 2019; Eccles et al., 1998; Hidi & Renninger, 2006; Krapp & Prenzel, 2011; Schiefele, 1999, 2009), are enthusiastic (Krapp, 1999), actively engage in the learning process (Pintrich & Schunk, 2002), are highly self-regulated (Pintrich, 2000; Zimmerman, 2000) and thus likely to achieve higher than their counterparts. In the present study, focus was on exploring students' physics learning motivation, their interest, and their usage of cognitive and metacognitive learning strategies during physics learning.

Motivation and interest play an important role in the learning process as discussed in chapter 2. However, whereas much research in motivation and interest has been conducted for the past years, majority of these researches have been conducted in science learning in general (e.g., Glynn & Koballa, 2006; Potvin & Hasni, 2014; Schumm & Bogner, 2016), chemistry (e.g., Ardura & Pérez-Bitrián, 2018, 2019; Salta & Koulougliotis, 2015) , and mathematics (e.g., Green et al., 2007; Hunt et al., 2021; Rotgans, 2015) . Even though results from these studies could inform physics learning, relying on them to inform decisions for interventions in physics education could be misleading. Although physics and mathematics are viewed as twin subjects (Amunga et al., 2011), their epistemological, pedagogical, and philosophical foundations differ significantly. Hence, students learning motivation for these two subjects differs, could have differing interest levels for the two subjects, would require different learning strategies, and consequently learner would require different forms of support for effective learning. However, limited research exists in the domain of physics learning motivation, interest, and usage of the cognitive and metacognitive learning strategies during physics learning especially in the developing countries.

One of the reasons for limited research in physics learning is the lack of instruments to assess learners' motivation. As a multi-dimensional construct that is explained through various theories e.g., Socio-cognitive theory (Bandura, 1986) and Self-regulation theory (Pintrich, 2000; Zimmerman, 2000) among others, several instruments (e.g., Science Motivation Questionnaire II, SMQ-II; Motivated Strategies for Learning Questionnaire, MSLQ) have been developed to encompass most of the motivation dimensions. However, majority these instruments were developed for different domains (e.g., science, engineering, chemistry) using different study context (e.g., Greek, German, USA). Thus, the first focus of the present study was to adapt and validate the SMQ-II to assess physics learning motivation using lower secondary school students in Uganda. The SMQII was used in the present study because of its theoretical foundation (Glynn et al., 2009). Also, results from studies (e.g., Ardura & Pérez-Bitrián, 2019; Salta & Koulougliotis, 2015; Schumm & Bogner, 2016) that had adapted the instrument to different subject domains and contexts indicate that the SMQ-II has a strong construct validity.

However, since no existent research had used the similar instrument to assess physics learning motivation in lower secondary school students to the best of our knowledge, we conducted an adaptation and validation study of the SMQ-II to Ugandan lower secondary school students (see Kwarikunda et al., 2020). Additionally, tests of measurement invariance were also conducted prior to examining gender differences in physics learning motivation. Conducting tests of measurement invariance is important to assess if boys and girls interpreted the instrument items in an equivalent way before mean comparisons.

Most of the few existing studies (e.g., Ekatushabe, Kwarikunda, et al., 2021; Kwarikunda et al., 2021)) have used a Variable-Centered Approach (VCA) to explore the interplay between motivation, cognitive and metacognitive learning strategy usage, and various learner outcomes (e.g., achievement). A major setback of variable-centered approaches is that they assume that relations between the constructs of motivation and the usage of the various cognitive and metacognitive learning strategies can be applied to all learners without catering for their individual differences (Vansteenkiste et al., 2009). More so, variable-centered approaches lack the ability to deal with heterogeneity within and between individuals (Wang & Wang, 2012).

To explore such individual differences, a researcher needs to use Person-Centered Approaches (PCAs). Studies that use PCAs do not only aim to categorise individuals into groups whose members have similar profiles that remain concealed in VCAs but also complement studies that used VCAs by providing useful heuristics for understanding how covariates associate with these latent profiles (Vansteenkiste et al., 2009; Wang & Wang, 2012). Specifically, we used latent profile analyses rather than traditional Cluster analyses. Unlike the traditional cluster analyses, e.g., *K*-means cluster analysis, which divide data into groups by measuring the Euclidean distance between the data points, latent Profile Analysis (LPA) relies on probabilistic modelling to identify the groups and place individuals within these identified groups (Vermunt, 2010). A detailed description of person-centered analyses was done in the methodology section.

Due to the uniqueness of the state of art of physics achievement in Uganda described above, the second focus of the present research was to explore students' physics learning motivation and their use of the cognitive and metacognitive learning strategies using PCAs. Specifically, there was need to reveal the various combinations of students' motivation and how these combinations are associated with interest and learning strategy use. Revealing these various combinations of students' motivation and cognitive learning strategy use could provide a basis for profile-based recommendations and interventions that address the specific learner needs in that profile. Interventions targeting a well-defined profile of students are more effective compared to those targeting everyone in a classroom or the overall classroom (Watt et al., 2019). Further, validating the profiles is important for theoretical clarification and description of the nature of the profiles (Gillet et al., 2017). Thus, after identifying the latent profiles in our study context, the identified profiles were validated by exploring differences and the predictive effects of gender, age, autonomy support, interest on the likelihood memberships into the profiles.

Precisely, students' physics learning motivation profiles were identified (Kwarikunda et al., 2021). Intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation were the motivational constructs assessed. The profiles identified were named based on the Self-Determination Theory (SDT) continuum (Deci & Ryan, 2000). A detailed description of the SDT continuum was done in the theoretical background section of the dissertation. To validate whether the identified profiles are meaningful according to the self-determination theory, firstly, tests of mean differences in usage of cognitive and metacognitive learning strategies between the identified profiles were done. We hypothesized that a profile characterized with high quality motivation contained students that reported frequent use adaptive cognitive and metacognitive learning strategies (such as elaboration and critical thinking) that promote deep learning (Schiefele, 1991) to complete the learning task with ambitious standards and excellence (Potvin & Hasni, 2014) . A profile characterized with low quality or quantity motivation was hypothesized to have members who use maladaptive cognitive and metacognitive learning strategies frequently. As noted in Schiefele (1999), students who use maladaptive cognitive learning strategies, e.g., rehearsal (for memorisation) use strategies that result in surface learning, have low motivation for learning, and are more likely to achieve less during Physics classes.

Secondly, likelihood of membership based on students' individual interest and attitudes was assessed. Since Zeyer (2010) argues that attitudes and interest might be much better predictors for explaining motivation to study Physics than gender and age, we hypothesized that students with higher attitudes towards learning physics and higher interest were more likely to be members of the high quality and quantity motivation profiles than their counterparts with low quantity or quality motivation.

Depending on the demands and complexity of the given academic task, students' use a variety of learning strategies (Duncan & McKeachie, 2005). As a subject that has been connoted abstract, complex, difficult to learn, and masculine (Amunga et al., 2011; Kwarikunda et al., 2020) the repertoire of cognitive and metacognitive strategies that students use to learn physics is important. As stated by Bouckenooghe et al. (2016), the way students engage with learning is rarely restricted to use of one single cognitive and metacognitive learning strategy. Pintrich (2000) also affirmed that no strategy is dominant or works equally for all individual learners for a given task. This implies that while some cognitive learning strategies are useful for some students, the same or similar learning strategies may not be equally useful to other students (Dowson & McInerney, 1998). Although several studies have explored the various cognitive and metacognitive learning strategy combinations, no similar study has been conducted for physics learning, especially in lower secondary school; a crucial level in which students develop an effective learning strategy repertoire (Rogiers et al., 2019) if properly guided and supported during instruction.

Since little is known about the cognitive learning strategies use repertoire during Physics learning among lower secondary school students' especially in developing countries, we sought to understand the various combinations of cognitive and metacognitive learning strategies that students use during physics learning. Understanding such combinations is vital for interventions that promote deep- level learning, critical thinking skills, basic skill sets required for technological discoveries and advancement (Gillet et al., 2017; Xie et al., 2022). Rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation strategies were the learning strategies that we focused on in the present study. A detailed description of these strategies is presented in the theoretical framework section and in article 3.

To validate the identified cognitive and metacognitive learning strategy profiles, tests of differences in intrinsic motivation and perceived autonomy support across the various identified profiles were done. As noted in Stolk and Harari (2014) and Schiefele (1991), the extent to which students make use of the cognitive learning strategies depends on their motivation. More so, a review of literature indicates that various forms of motivation account for differences strategy use (Manganelli et al., 2019), and consequently academic achievement. However, since it is unclear of how intrinsic motivation and perceived teacher autonomy support differ in various groups of learners depending on their cognitive strategy use specifically in lower secondary school, the present study focused on filling such a knowledge gap.

Prior to identifying the cognitive and metacognitive learning strategy use profiles, gender differences in cognitive and metacognitive strategies were explore. A review of previous research reports contradicting findings on the preference of the usage of different learning strategies during science learning. Whilst some studies noted stable gender differences in learning strategy use (Meece & Jones, 1996; Rogiers et al., 2019; Wolters & Pintrich, 1998), other studies reveal that girls show higher levels of cognitive strategy use (Wolters & Pintrich, 1998), are more knowledgeable about the various effective strategies (OECD, 2010), and tend to utilize more learning strategies (Rogiers et al., 2019) than boys. In other studies, girls prefer to use memorization strategies (e.g., rehearsal), whilst boys prefer to use elaboration strategies (Meece & Jones, 1996; OECD, 2010). On the contrary, Niemivirta (1997) reports that boys used more memorization strategies than girls. In other studies, there were no significant gender differences in cognitive strategy use (Akyol et al., 2010; Metallidou & Vlachou, 2007). It should be noted that these studies were conducted in different domains rather than physics. None the less, It is possible that these differences are reflective of context and nature of the academic tasks' differences (Duncan & McKeachie, 2005). Thus, we recognise from these studies that preference for a specific learning subject by different genders could also be attributed to the nature of subject domain, students' interest in the subject, and the value students attach to the material learnt. However, as earlier stated, there is limited research about the repertoire of learning strategies used during physics. Thus, it is unclear of the gender differences in cognitive strategy use among ninth grade students during Physics learning. An exploration of gender differences in cognitive strategy use during Physics learning is vital for gender-specific recommendations and interventions.

A review of literature highlights that motivation is malleable in nature and thus can change over time (Osborne et al., 2003). Specifically, Xie et al. (2022) argue that the changes in motivation are more complex than just an increase or decrease, especially when motivation is considered as a multi-faceted construct in motivational research. A change in mean of one of the motivational constructs could imply that there are many within-person changes that occur in a sample. More so, if student's motivation is changing as they advance from one grade to another, we expect that their (Meta) cognitive learning strategies usage also changes quantitatively and qualitatively, given that motivation influences cognitive and metacognitive learning strategy use during STEM learning (Ekatushabe, Nsanganwimana, et al., 2021; Kwarikunda et al., 2021; Schiefele, 1999). Although Variable- Centered Analyses (VCA) can detect general (mean) changes in students' physics learning motivation and cognitive learning strategies use, these approaches cannot be used to examine the complex changes that occur in different subgroups (latent profiles) of students within the sample with increase in time.

To uncover such complex changes, there is need to employ longitudinal person-centered analyses. However, to the best of our knowledge, there is no existing longitudinal person-centered research that examines changes in lower secondary school students' motivation and cognitive strategy use during Physics learning. Thus, it is unclear of the changes that occur in secondary school students' (Meta)cognitive learning strategy use with time. To address this knowledge gap, an examination of the changes in students' motivation and cognitive learning strategies use was done. Understanding such changes in motivation patterns can better inform STEM teachers' pedagogy to support the development of motivation.

1.2 Structure of the Thesis

After opening a general introduction of the arguments for the importance of researching motivation, interest, and the use of learning strategies in educational settings, in Chapter 2, a literature review is done. Specifically an extensive exploration of the relationship of this study's variables within the self-regulated learning framework is done. Section 2.1 is a discussion of motivation as component of self-regulated learning. In this section, the role of motivation in science learning in general and physics learning is explained. In section 2.2, a review of strategies use literature is done. Specifically, this section addresses the question of "how" students learn physics and the various factors affecting information processing of the physics learning material whilst using various learning strategies . The remainder of Chapter 2 explores interest as a component of self-regulated learning and how other factors such as gender, autonomy support that may influence students' interest, motivation and learning strategy use during physics learning. At the end of Chapter 3 is literature on how interest, motivation, and learning strategies use during physics learning are likely to change with time.

Chapter 3 present the goals and methodology underpinning this thesis. A detailed description of the sample selection process, sample composition as well as data collection procedures and measures is done. In addition, there is a detailed discussion of the ethical considerations and procedures in light of American Psychological Association guidelines.

Given that this thesis is publication-based, chapters 4, 5, 6 and 7 are composed of the published and unpublished articles. In each chapter, a detailed introduction, methodology, results, and discussion of results of that article are done. Chapter 4 is a published article in the African Journal of Research Mathematics, Science, and Technology (2021). This chapter reports results of the pilot study in which an adaption and validation of science motivation questionnaire-II for physics learning in Ugandan context was done using a sample of 374 (56% females) randomly selected 8th grade students.

Upon obtaining a valid instrument, data at time point one (T1) was collected. In reference to the study's goals highlighted in chapter 3, person-centered analyses were conducted to reveal various combinations of students' physics learning motivation. Thus, the second article included in this thesis as Chapter 5 was developed and later published in the African Journal of Research Mathematics, Science, and Technology (2022).

Chapter 6 constitutes of a published article in Humanities and Social Sciences Communications (2022). In this article, students' repertoire of their learning strategy usage and how these patterns of their learning strategies use relates to gender, intrinsic motivation, and students' perceived teacher autonomy support were reported. Similarly to article 2, results of this article were obtained from the first data wave we collected.

Last but not least, Chapter 7 presents an article in preparation for journal submission. In this article are results of a longitudinal track of students' motivation, interest and their learning strategies use over time. The article presents results from both variable-centered approaches and person-centered approached of two wave data. More so, the effects of change in students' autonomy support and individual interest on the profile membership transition probabilities were also reported.

Finally, at the end of this thesis is Chapter 8 which presents the general discussions of the study findings indicating similarities and differences with other study findings in the field of science learning in general and physics learning in specific. More so, educational implications of the findings and limitations of the studies are highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical Background

Since the late 1970's, fostering lifelong learning became an important educational goal in many countries worldwide (Rogiers et al., 2019). With the growing need to train self-reliant, independent, and critically thinking citizens that meet the constantly evolving demands of the job and market world (Muwonge et al., 2020), many countries consequently shifted their pedagogical practices from teacher- centered approaches to learner-centered approaches. Consequently, control of the learning process in the learner- centered classrooms shifted from the teachers to the learners. Thus, in such classrooms, the role of teachers shifts to "facilitators" of the learning process whilst learners solely take the responsibility to understand their learning environment and control over "why", "how" and "when" they should learn a given academic task. In this dissertation, we focused more on "why" and "how" students learn Physics.

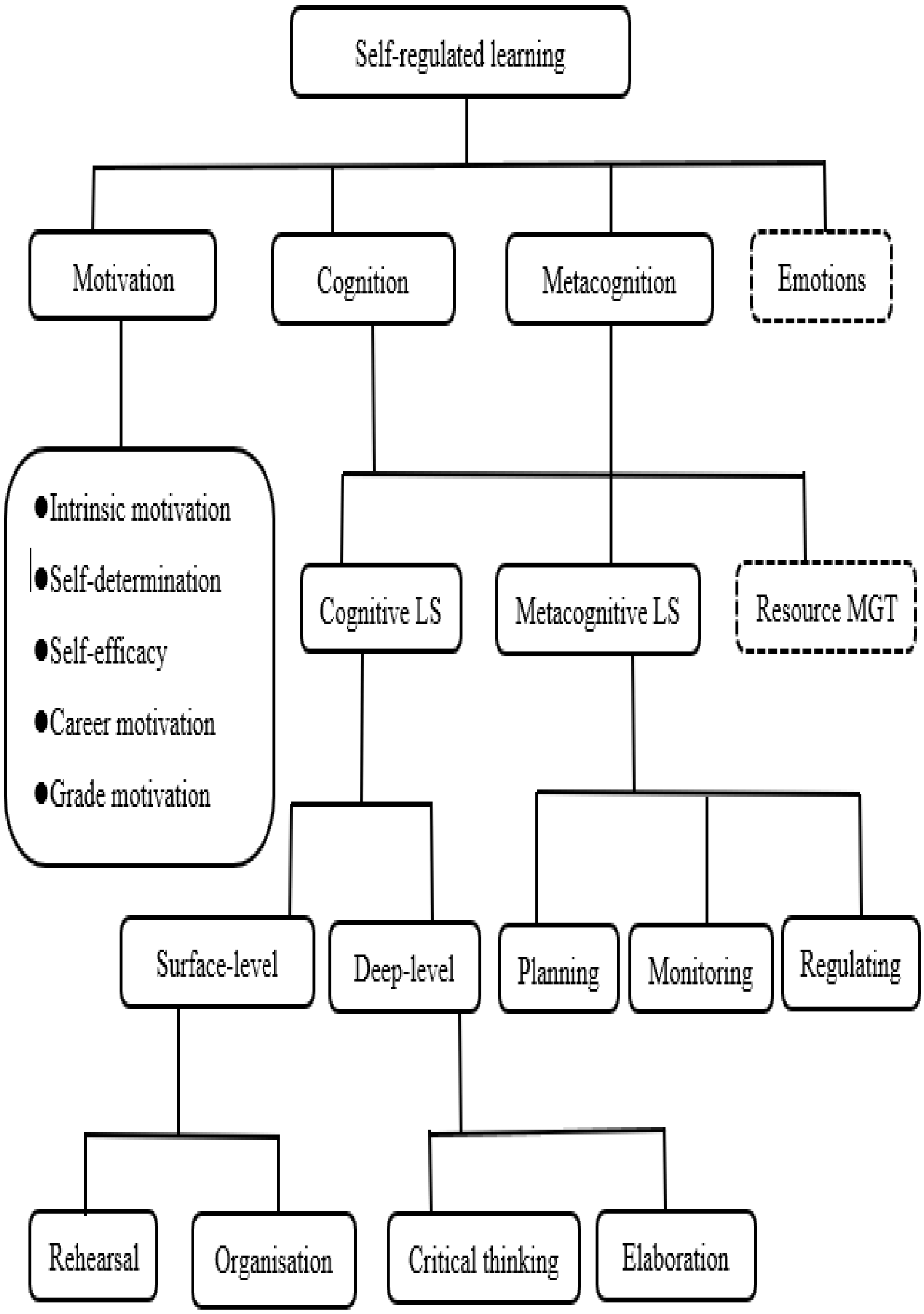
Several theorists (e.g., Bandura, 1986, 2001; Bandura et al., 2006; Pajares & Schunk, 2001; Pintrich, 2003) have conceptualized various aspects that explain "why" or what drives students during learning. This driving force of students' learning has been conceptualized as motivation (Pintrich, 1999; Pintrich & Schrauben, 1992; Pintrich et al., 1993; Potvin & Hasni, 2014). Motivation is defined as "the internal state that arouses, directs and sustains learning behaviour" (Glynn et al., 2011, p. 1160). Learning motivation theorists (e.g., Bandura, 2001; Deci & Ryan, 2008; Pintrich, 1999; Ryan & Deci, 2000) report that students learn for the value they attach on the academic task (Eccles & Wigfield, 2002), because of the inner satisfaction they obtain from the learning process (Ardura & Pérez-Bitrián, 2019; Hidi & Renninger, 2006; Niemivirta & Tapola, 2007; Schiefele, 1991), for their curiosity and expectations (Ekatushabe, Nsanganwimana, et al., 2021; Krapp, 1999; Krapp & Prenzel, 2011), and their self-perception of ability to perform better on a given task (Zimmerman, 2000; Zusho et al., 2003).

However, there is a recognition that motivation alone is not enough for completion of an academic task (Linnenbrink & Pintrich, 2002), but rather students need both the cognitive skills ("how") and the motivational will to do well in school (Pintrich & Schunk, 2002). Integration of motivational and cognitive factors came because of a shift in motivational theories from traditional achievement motivation models to social cognitive models of motivation (Linnenbrink & Pintrich, 2002; Pintrich & Schunk, 2002).

Socio-cognitive models of motivation (Bandura, 1986, 2001; Bandura et al., 2006; Pajares & Schunk, 2001; Pintrich, 2003; Zimmerman, 2000) assume that motivation (a) is a dynamic, multifaceted phenomenon, (b) is not a stable trait of an individual but rather is more situated, contextual, and domain specific, and (c) that learning motivation is shaped by individual's active regulation in addition to their demographic characteristics, personal traits and contextual factors (Linnenbrink & Pintrich, 2002). Individual regulation is also referred to self-regulation. Students' learning is viewed as most effective when it is self-regulated, which occurs when students understand, monitor, and control their motivation and behaviour (Glynn et al., 2011), leading to desirable learning outcomes. Figure 2.1 below is a flow diagram showing the various integrated components of self-regulated learning (as proposed by Pintrich, 2000).

Figure 2.1

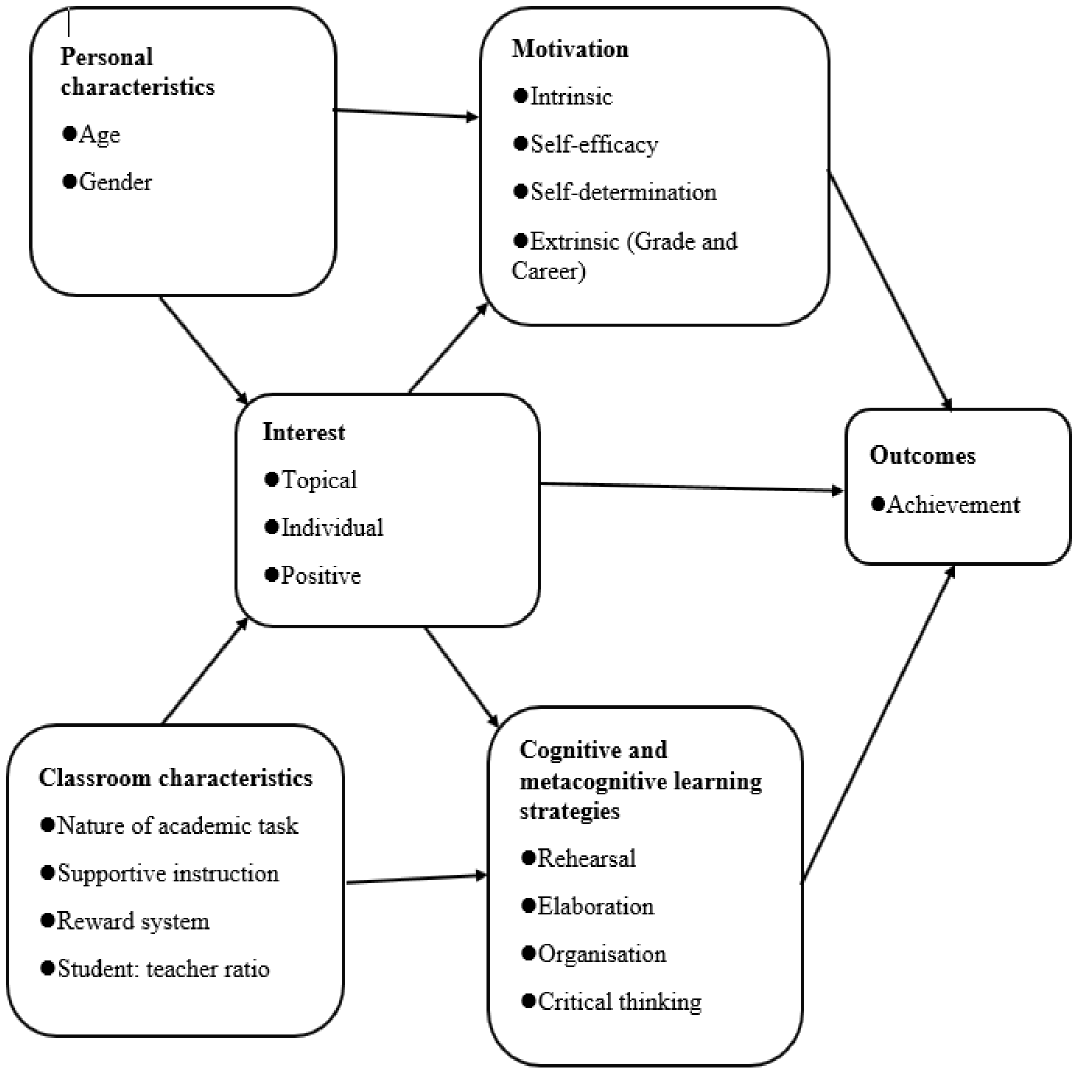
Figure showing the various components of self regulated learning from the social-cognitive perspective.



Note. The variables in the broken boxes were not included in the present study context. Cognitive LS: Cognitive learning strategies; Metacognitive LS: Metacognitive learning strategies; Resource MGT: Resource management

Figure 2.2

Conceptual framework of the present study.



Although self-regulated learning has a history in cognitive psychology, its origin is traced back to the socio-cognitive learning theory (Bandura, 1986, 2001; Bandura et al., 2006; Schraw et al., 2006). As illustrated in figure 2.1. above, self-regulated learning is as a result of various cognitive, metacognitive, emotional, and motivational components of an individual (Pintrich, 2000; Zimmerman, 2000). Also, Figure 2.2. displays the general conceptual model of the present study. In this conceptual model, we propose that certain personal characteristics such as age, gender along with classroom contextual factors such as autonomy supportive instructions help to shape why an individual engages and responds to a physics learning task, which in turn influences students' repertoire of their cognitive and metacognitive skills.

In line with the social cognitive perspective of motivation, the conceptual model assumes that the relationships between the various components of self-regulation are reciprocal and, thus, can mutually influence one another. For purposes of this study, we focused only on motivation, cognition and meta-cognition components of self-regulated learning. In the following sections, a discussion of the various components of the self- regulation learning framework is done, with each part not in isolation but rather in relation with other components as proposed in the conceptual model.

2.2 Motivation as a component of Self-regulation

Motivation includes the various beliefs that drive the use and development of cognitive and metacognitive skills during learning (Pintrich, 2000). Within the self- regulation framework, motivation plays an important role in explaining the value and belief system that students have when it comes to goal setting and choice of the learning strategies to use (Pintrich et al., 1993; Zimmerman, 2000). Due to its multi-dimension nature, different models of self-regulation highlight different components of motivation. Pintrich et al. (1993) and colleagues' model encompasses self-efficacy, intrinsic motivation, and extrinsic motivation as the motivation constructs.

Self-efficacy is defined as students' judgments of their capabilities to perform a task, as well as their beliefs about their agency in the course (Zusho et al., 2003). Bandura (1981) defines self-efficacy as the individual's perception of his/her ability in accomplishing learning tasks. Similarly, Pajares (1996) defines Self-efficacy as the individual's belief of competence to carry out tasks and attain certain results. On contextualising whilst merging these definitions, self-efficacy during physics learning is defined as students' beliefs and perceptions of their agency and abilities to execute behaviours necessary to carry out learning a physics task with certain results. In the contextualised definition, we are conscious of the specificity of self-efficacy (Bandura et al., 1999), and thus we limited ourselves to generalising the definition by using the word "subject". Nevertheless, self- efficacy is important for self-regulated because it reflects the confidence students have in their ability to exert control over one's own motivation, behaviour, and social environment.

Self-efficacy affects the extent to which learners engage in a challenging task (Schraw et al., 2006; Zimmerman, 2000) and the quantity of effort and the willingness to persist at such tasks (Bandura et al., 1999; Schunk, 1989, 1991). When students have more positive self-efficacy, they believe that they are capable of accomplishing learning tasks regardless of the tasks' difficulty (Pajares, 1996), are more likely to work harder, persist, use adaptive and appropriate study skills, and eventually achieve at higher levels (Linnenbrink & Pintrich, 2002) than their counterparts. During physics learning, there are many student -reported challenges such as the abstract nature of the subject, the applied mathematical composition of physics as well as the comprehension section of the subject (Kwarikunda et al., 2020), highlighting the need for high self-efficacy. Thus, it is important for students to believe that they can conduct physics learning tasks regardless of the challenges.

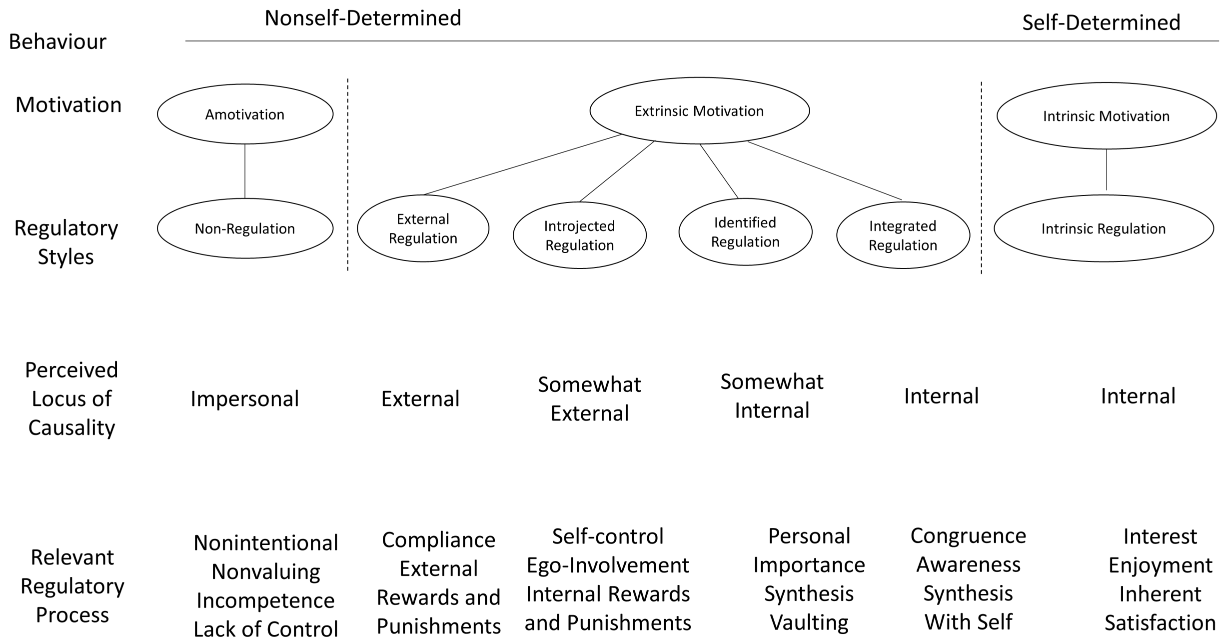
The second motivational component is intrinsic motivation. Intrinsic motivation has been defined by many researchers (Deci & Ryan, 2000; Ryan & Deci, 2020). In their definitions are sets of key words used: "for their own sake" and "their Inherent interest and enjoyment". From these definitions, intrinsic motivation during physics learning can be defined as the drive to take part in physics learning tasks for the inherent satisfaction, enjoyment and interest derived from the tasks rather than for the pressures and rewards attached to the physics task. Intrinsically motivated students pursue learning activities because of personal choice and absence of external contingencies regardless of the difficulty of the task (Vansteenkiste et al., 2009), are likely to engage in effective cognitive learning strategies (Deci & Ryan, 2000; Hidi, 2001; Hidi & Harackiewicz, 2000; Krapp, 1999; Schiefele, 1991), are more successful in learning new concepts and show better understanding of the learning matter (Stipek et al., 1996), remain highly focused throughout the activity (Larson & Rusk, 2011), follow clearly defined goals (Eccles et al., 1998), remain self-critical and realistically reflect on their own actions (Csikszentmihalyi & Nakamura, 2014), are curious (Vallerand et al., 1986) and are not anxious or afraid to fail (Pintrich & Schunk, 2002). Additionally, because of the enjoyment, and experience of volition, students keep engaging in the self-sustaining activity, and are more likely return to it in the future as a career (Hidi & Harackiewicz, 2000).

Several researchers have explored relationships between intrinsic motivation, other components in the self-regulated learning framework and learning outcomes. Positive predictive relationship between intrinsic motivation and learning (Lepper et al., 2005; Ryan & Deci, 2009; Schiefele et al., 1992) precisely, predictive effects of intrinsic motivation on students' increased use of strategies, (Hidi, 2001; Hidi & Harackiewicz, 2000; Krapp, 1999), and on their greater cognitive activity and deeper cognitive processing of the task at hand (Schiefele, 1999). To experience intrinsic motivation, students need to feel challenged, have a sense of control, and deep attention (Larson & Rusk, 2011). Ryan and Deci (2000) emphasize that because challenge and attention are experienced as emergent from the self, students will experience intrinsic motivation as self-determined.

Contrary to intrinsic motivation is extrinsic motivation, a form of motivation that is hinged on the frequency and quality of external contingencies. Extrinsically motivated students engage in a wide variety of behaviours as a means to an end and not for their own sake (Deci, 1975). For example, learners participate in a learning activity for the sake of external rewards such as grades rather than for the enjoyment the task brings. Several subtypes of extrinsic motivation exist. Glynn and colleagues (2011) distinguished extrinsic motivation into two subtypes; the drive to engage in learning activities only for grades (grade motivation) on one hand and the drive to engage in learning activities for future career (career motivation) on the other. Thus, one could say that extrinsic motivation is because of performance goals or mastery goals. Contrary to Glynn et al. (2011), Ryan and Deci (2020) propose that extrinsic motivation contrasts in content and character. In one of their research projects, they proposed that there are four subtypes of extrinsic motivation that are classified on a continuum between amotivation and intrinsic motivation (Deci & Ryan, 2008).

Figure 2.3

A representation of the self determination continuum showing various types of motivations.



***Note*.** This figure was adapted from Ryan and Deci (2000).

As illustrated in figure 2.3, extrinsic motivation can be: External regulation, Introjected regulation, identified regulation, and integrated regulation. External regulation concerns behaviours driven by externally imposed rewards and punishments (Deci & Ryan, 2008; Ryan & Deci, 2000). This form of motivation is typically experienced as controlled and non-autonomous (Ryan & Deci, 2020). Introjected regulation behaviours are regulated by the internal rewards of self-esteem for success to avoid emotions of anxiety, shame, or guilt for failure (Ryan & Deci, 2020; Vansteenkiste et al., 2009). Whilst identified regulated students consciously endorse the value of an activity high degree of volition or willingness act, integrated regulated students engage in tasks because they find these to be congruent with other core interests and values (Ryan & Deci, 2000; Vansteenkiste et al., 2009). In other words, students are motivated based on the sense of value they have for the learning task.

From the various subtypes of extrinsic motivation discussed above, it is clear that a general quantification of extrinsic motivation for a group of students could be misleading. For example, whereas both external regulation and integrated regulation are both extrinsic forms of motivation, an externally regulated student is externally controlled whilst during integrated regulation, students view the learning activities as worthwhile, even if the activities are not enjoyable (Ryan & Deci, 2020). Several studies affirm that indeed motivation varies in quantity and quality (Vansteenkiste et al., 2009) controlled motivation predicts a broad variety of undesirable outcomes such as use of maladaptive coping strategies (Ryan & Connell, 1989), less engagement in adaptive meta-cognitive strategies (e.g., Vansteenkiste et al., 2009; Zusho et al., 2003), superficial cognitive processing (Vansteenkiste et al., 2009), more procrastination (Senécal et al., 2003), and lower achievement (Soenens & Vansteenkiste, 2005).

To deviate from Pintrich (2003), Glynn and colleagues (2011) include a self-determination as a component of motivation. self-determination is defined as students' ability to recognize that they have choices and control over what they do during learning (Reeve et al., 2003). In science learning, Black and Deci (2000) refers to self-determination as the control students perceive they have over their learning of science activities. On extending these two definitions, self-determination during physics learning is defined as the student's ability to recognise and believe that they have choices and control over their physics learning process.

For learners to be self-determined, they need to be autonomous. Autonomy is defined as a perception of being the source of one's own learning behaviours (Deci & Ryan, 2000; Manganelli et al., 2019). Autonomous students do not only achieve their learning goals, but they also have a perception of psychological freedom and satisfaction. Developing students' sense of autonomy students results into an improvement students' self-determination and often an improvement in their intrinsic motivation (Reeve et al., 2003). When students feel like they have control over their success in a classroom, they are more likely to work hard in that class. A lack of self-determination could have a lasting impact on students' motivation to learn, and then their achievement (Glynn et al., 2011).

2.3 Cognitive and Metacognitive Learning Strategies use

As a subject that is considered difficult by most students, due to the learning processes involved a conceptual understanding at an abstract level (Angell et al., 2004; Sidin, 2003) that also requires students to deal with diverse types of representations such as formulas, calculations, graphics representations (Saleh, 2014), how students learn such content is fundamental. The self-regulated learning framework addresses the question of "how" students learn by proposing a set of information processing and regulating strategies. Cognition includes different skills learners use to encode, memorise, and recall information (Schraw et al., 2006). Cognitive learning strategies involve basic and complex ways in which knowledge is chosen, retained, and processed in relation to previously acquired knowledge (Pintrich et al., 1993). Metacognition involves skills learners use to understand, monitor, and regulate their cognition process (Pintrich, 2000; Zimmerman, 2000). In the cognitive and metacognitive components of self-regulated learning, Zimmerman (2000) stresses that for improved learning, students must use a variety of individual tactics and skills, skills also identified as learning strategies by Pintrich and colleagues (1993).

Depending on the demands and complexity of the given academic task, learners differ in their self-regulation and thus, use a variety of learning strategies (Duncan & McKeachie, 2005). Additionally, when students perceive the value of learning tasks, they use deep-level learning strategies (such as elaboration) to learn (Pintrich & Schunk, 2002). Learning strategies are a set of skills that students choose and effectively use to acquire knowledge and accomplish different learning tasks and goals (Pintrich et al., 1993). Learning strategies can be categorized according to their nature (i.e., cognitive, metacognitive, and motivational) and level of depth of information processing and internalisation (Rogiers et al., 2019).

Superficial strategies are strategies that only require surface-level processing whilst deep level strategies are those strategies that require more deeper processing of course material (Zusho et al., 2003). Deep-level strategies are aimed at deep understanding and active transformation or application of information while surface-level strategies aim at memorisation and basic comprehension without any information integration (Rogiers et al., 2019; Schiefele, 1991; Zusho et al., 2003).

Pintrich (2003) conceptualized five components of cognitive and metacognitive strategy use, that is rehearsal, elaboration, organisation, critical thinking, and metacognitive self-regulation. Rehearsal involves repeated recitation, writing, and naming of the items and definitions to be learned. For example, during physics learning rehearsal involves repeated writing of formulae until a student can write them properly, verbal recitation of definitions, formulae and symbols, and practising saying the desired material to their friends over and over. Rehearsal is a basic learning strategy through which information in working memory is activated (Pintrich, 2000).

Organization is a more active process during which students select appropriate information through clustering, outlining, and selecting the main idea in learning passages. Certain topics in physics contain learning objectives that require students to extract information from long passages or scenarios. In such cases, students could use organization strategies like writing summary of physics material, outlining information they find useful in a class among others. However, both learning strategies do not allow construction of connectivity among new information with prior knowledge but rather emphasize memorization (Pintrich et al., 1993). Consequently, constant use of rehearsal and organisation strategies promotes surface-level learning (Schiefele, 1991; Zusho et al., 2003).

On the other hand, for deep learning to occur, learners need to use high-order strategies like elaboration and critical thinking (Schiefele, 1991). By building internal connections between items to be learned, students use elaboration strategies such as generative note taking, using different colour codes (pens), making analogies, and effective note taking to store information into long-term memory (Pintrich et al., 1993). At the same time, elaboration strategies help students integrate new learning with existing knowledge (Pintrich et al., 1991). When students use elaboration strategies to establish connections between new materials, visual imagination, and previous knowledge, they increase the meaning of new information (Wolters et al., 2005), creating deep meaning between units of information (Obergriesser & Stoeger, 2020).

Critical thinking involves a variety of skills such as the learners' ability to identify the source of information, analyse its credibility, reflect on whether that information is consistent with their previously acquired knowledge, apply previously acquired knowledge to new learning situations, make evaluations with respect to the standards of excellence, draw conclusions based on their critical thinking (Linn, 2000; Pintrich et al., 1993), and elaborate their personal opinion about the topics being studied (Cred & Phillips, 2011). Constant use of critical thinking strategies also improves students' problem-solving skills (Pintrich & Schrauben, 1992).

Metacognition involves students' knowledge of their cognition and their ability to control their cognition. In the self- regulation framework, learners have the responsibility to set learning goals, plan, monitor and evaluate their learning at various points during the learning process (Zimmerman, 1990). Planning involves the selection of appropriate strategies depending on the task at hand, allocating resources, and setting the learning goal (Pintrich et al., 1993; Schraw et al., 2006). Through planning activities students activate relevant aspects of prior knowledge, hence organisation and comprehension of material to be learned becomes easier (Pintrich et al., 1993).

Through monitoring strategies, learners can track their attention, make judgements of their motivation levels and effectiveness of the learning strategies (Pintrich, 2003). Evaluation usually involves accessing their learning goals and effectiveness of their learning strategies. Through evaluation, learners can continue to use a given set of learning strategies deemed effective and or replace those strategies that they find ineffective for a given learning task. Also, through evaluation, learners self-test their learning achievement. Students' use metacognitive self-regulation strategies to mobilize various consciousness and behaviour to participate in the learning process, which can help students effectively implement cognitive strategies (Obergriesser & Stoeger, 2020). Generally, researchers have shown that it is more adaptive to use deeper processing strategies, in terms of long-term retrieval of information (Pintrich, 2000; Pintrich & Schrauben, 1992).

2.3.1 Patterns of Students' Motivation.

Motivation psychologists report that individual differences exist in students' motivation (Hickendorff et al., 2018), across the various Science disciplines (Glynn et al., 2011) and contexts. This implies that particular motives may be of immense importance to some students while at the same time the same motives may be of less important to other students. More so, within the same domain, these motives are likely to change as students' progress from one class to another (Corpus et al., 2009; Eccles et al., 1998; Lepper et al., 2005). Variable-centered approaches to data analysis are limited when it comes to examine such individual differences (Gillet et al., 2017; Wang & Wang, 2012) (Meyer & Martin, 2016). As discussed in Article 2, person centered approaches are more advantageous when uncovering such patterns.

A review of research that used person-centered approaches to examine individual differences in science learning indicate that students have different patterns of motivation (e.g., Corpus & Wormington, 2014; Gillet et al., 2017; Hayenga & Corpus, 2010; Oga-Baldwin & Fryer, 2018; Xie et al., 2022). In these studies, results indicate that students' motivation patterns can (1) be qualitative or quantitative patterns , (2) be autonomous or controlled patterns, and (3) be classified on the self-determination continuum (figure 2.3). However, whereas some quality profiles are highly correlated with positive learner outcomes (Hayenga & Corpus, 2010; Kwarikunda et al., 2021; Muwonge et al., 2020), possession of high quantity motivation could have equally advantageous positive effects on the learner outcomes.

Additionally, students' motivation patterns change with time, given that motivation is malleable in nature (Bouffard et al., 2003). These changes in motivation for science learning differ according to educational levels or class grade (Hayenga & Corpus, 2010). Some students experience decreases in their motivation or in one of the motivation dimensions while other students experience an increase. Wigfield and Eccles (2000) state that the overall negative change in academic motivation begins in early adolescence-a time when students are in their first or second academic year of their lower secondary.

However, as Xie et al. (2022) argues, changes in motivation are not just an increase or decrease but rather more complex, especially when motivation is considered as a multi-faceted construct in motivational research. These changes are even more complex when learners are moving from one class grade to another. Xie and colleagues (2022) recommend longitudinal studies, preferably using person-centered approach to examine such changes. Thus, the present study does compliments existing longitudinal research in motivation, but also provides a clearer exploration of how these changes could be influenced by gender, students' attitudes towards physics and their individual interest.

2.3.2 Patterns of Students' Cognitive and Metacognitive Learning Strategy usage.

Given that self-regulation is context dependent (Zimmerman, 2000), the way students engage with learning is rarely restricted to use of one single cognitive learning strategy (Bouckenooghe et al., 2016). Pintrich (2000) also affirmed that no strategy is dominant or works equally for all individual learners for a given task. This implies that while some cognitive and metacognitive learning strategies are useful for some students, the same or similar learning strategies may not be equally useful to other students (Dowson & McInerney, 1998). For example, whilst Japanese students reported to use mostly memorization, summarization, and rehearsal while learning less enjoyable and abstract academic tasks (Purdie et al., 1996), Turkish 7^{th} grade science students reported frequent use of metacognition, rehearsal, and elaboration strategies as compared to other cognitive and metacognitive learning strategies (Akyol et al., 2010).

However, a generalisation of cognitive and metacognitive learning strategy use on sample level is limited by inability to reveal existent individual differences in learning strategy use. Given that different students find different strategies useful as compared to others (Bouckenooghe et al., 2016), unmasking such combinations of strategy use is a vital basis that can be relied on for instructional improvement.

Several researchers have explored various patterns of cognitive and metacognitive learning strategies. Whilst using elementary school students, Merchie and colleagues (2014) identified 4 groups of learners they identified as memorisers, mental learners, information organisers, and integrated strategy users. In university students, Zheng et al. (2020) identified four profiles of self-regulated learners: competent learners, reflective-oriented learners, minimally regulated learners, and cognitive-oriented learners, with competent learners reporting highest scores on motivational process and cognitive strategy use. Heikkilä et al. (2012) also identified three profiles of learners based on their learning strategy use i.e., non-regulating students, non-reflective students, and self-directed students. Similar studies (e.g., Liu et al., 2014; Muwonge et al., 2020; Ning & Downing, 2015). However, it should be noted that none of the studies above address the knowledge gap of lack of person-centered studies in cognitive and metacognitive learning strategy use during physics learning. nevertheless, review of these studies informs about the possibility of likely profile similarity and or for comparison purposes.

2.3.3 Gender differences in students' Motivation and Cognitive Learning Strategies use

Previous studies have reported gender disparities in students' motivation (e.g., Ardura & Pérez-Bitrián, 2019; Britner & Pajares, 2001; Glynn et al., 2011; Meece & Jones, 1996; Opolot-Okurut, 2010; Salta & Koulougliotis, 2015; Schraw et al., 2006) and cognitive learning strategies use (e.g., Meece & Jones, 1996; OECD, 2010; Rogiers et al., 2019; Wolters & Pintrich, 1998) . In most of these studies, gender differences in motivation favour male students in learning of Science and Mathematics among students at secondary school level (e.g., Meece & Jones, 1996). For example, male students are more self- efficient than their female counterparts (e.g., Ardura & Pérez-Bitrián, 2019; Britner & Pajares, 2001; Opolot-Okurut, 2010). In terms of domain specificity, Glynn et al. (2011) noted whilst boys had better motivational orientations towards Physical Sciences, girls whose motivational orientations were more inclined to Biological Sciences. Additionally, among low-ability Science students, boys tend to show higher proficiency motivation compared with girls (Meece & Jones, 1996).

On the contrary, studies (e.g., Ardura & Pérez-Bitrián, 2019; Opolot-Okurut, 2010) indicate that although female students are not more motivated than males, they report higher scores on more than half of the dimensions of motivation dimensions they had studied. For example, In Germany, Schumm and Bogner (2016) noted that although there were no gender differences in students' overall motivation 10th grade students, gender differences existed in self-determination in favour of female students. Similar findings were reported by Ardura and Pérez-Bitrián (2018) in Spain and Salta and Koulougliotis (2015) in Greece. More so, gender differences were noted in intrinsic motivation, with girls being more intrinsically motivated than boys. In some studies, no gender differences were reported in students' motivation (e.g., Ekatushabe, Kwarikunda, et al., 2021; Kwarikunda et al., 2020; Salta & Koulougliotis, 2015).

In terms of cognitive and metacognitive learning strategies use, stable gender differences in learning strategy use (Meece & Jones, 1996; Rogiers et al., 2019; Wolters & Pintrich, 1998). Research indicates that girls show higher levels of cognitive strategy use (Wolters & Pintrich, 1998), are more knowledgeable about the various effective strategies (OECD, 2010), and tend to utilize more learning strategies (Rogiers et al., 2019). Specifically, Niemivirta (1997) concluded that boys are rote learners.

Contrary to Wolters and Pintrich (1998) and Niemivirta (1997), Meece and Jones (1996), and OECD, 2010 reported that girls prefer to use memorization strategies, that result into surface-level learning than boys who prefer to use deep-level learning strategies (e.g., elaboration strategies). Niemivirta (1997) concluded that boys are rote learners since they outperformed girls when using rote learning strategies.

As discussed above, it is clear that the role of gender in students' motivation and cognitive learning strategies usage to learn Science is unclear. Findings from Glynn et al. (2011) and Duncan and McKeachie (2005) suggest that gender discrepancies are not only context specific but also domain dependent. Most of the present studies in literature are in Science as a general subject or mathematics. The few motivational studies that exist (e.g., Glynn et al., 2011) were conducted in developed countries using mostly university students, leaving a knowledge gap on the gender differences in motivation towards learning Physics. To complement the existing studies, the present study employed person-centered approaches to examine relations between gender and motivation, cognitive and metacognitive learning strategies usage during physics learning. Further, findings from the present study could aid in developing interventions that are consistent with the students' gender motivational requirements for developing countries like Uganda.

2.4 Conceptualisation of Interest

In earlier studies (between 1988 to 1990) interest was viewed as a lay term for intrinsic motivation(see Schiefele, 1999). As time went by, Schiefele (1991) noted that although interest and intrinsic motivation might seem similar concepts because they of their intrinsic nature, they differ because intrinsic motivation does not capture all of the essential aspects of interest. Of the interest aspects that are not covered in intrinsic motivation research is its content-specific and domain-specific concept. Two forms of interest were conceptualised: individual interest, situation interest (Hidi, 2001; Schiefele, 1991). Whereas Individual interest is viewed that form of interest that is enduring, and preference for certain topics, subject areas, or activities, Situation interest is emotional state brought about by situational stimuli (Hidi & Renninger, 2006; Krapp, 1999; Renninger, 2000; Schiefele, 1991). In this dissertation, we focused on individual interest.

Hidi and Renninger (2006) define interest in science as 'both the state of heightened affect for Science and the predisposition to re-engage in science again' (p. 114). On extending this definition to Physics learning, individual interest refers to an enduring directive force that drives the ongoing feelings and deepening relations of a student to Physics. Individual interest facilitates sustained attention and effort during learning, maintains enjoyment of focused and continued engagement in a task for the sake of the task itself, and enhances the desire for proficiency (Schiefele, 1999). Learners with high individual interest for learning Physics report elevated levels of intrinsic motivation, use a variety of adaptive cognitive learning strategies, highly endure during difficult learning tasks and are highly self-regulated compared with their counterparts with low interest (Kwarikunda et al., 2020). Individual interest increases as knowledge and the accompanying value (grade or career motivation) for the subject increase

(Schiefele, 1991).

In this project, focus was on examining the predictive effect of individual interest on motivation and cognitive learning strategies use during physics learning. In Previous studies, reports of predictive associations between students' interest and related motivation for learning are contradiction (e.g., Schiefele, 1991). In Some studies, it is revealed that interest in science predicts motivation (e.g., Ardura & Pérez-Bitrián, 2019) whilst in other studies the reverse is reported (e.g., Leaper et al., 2012). No such similar studies have been conducted in physics learning. Thus, an exploration of the predictive effects of individual interest on students' motivation and cognitive learning strategies was done whilst using person-centered approaches (Article 2).

CHAPTER 3

GOALS AND METHODOLOGY

3.1 Research Goals

In chapter 2, the role of Motivation and interest in the learning process have been clearly discussed. However, much of empirical evidence that supports the role of motivation and interest in various subject domains and study contexts been conducted in science learning in general (e.g., Glynn & Koballa, 2006; Potvin & Hasni, 2014; Schumm & Bogner, 2016), chemistry (e.g., Ardura & Pérez-Bitrián, 2018, 2019; Salta & Koulougliotis, 2015), mathematics (e.g., Green et al., 2007; Hunt et al., 2021; Rotgans, 2015) and mostly in developed countries.There is hardly any research that explores students' physics learning motivation, their interest and usage of learning strategies in lower secondary schools in developing countries especially in the Sub-Saharan African region. More so, much as physics and mathematics are viewed as twin subjects (Amunga et al., 2011), their epistemological, pedagogical, and philosophical foundations differ significantly. Although to some extent results from these studies could inform physics learning, to a larger extent, relying on results from such studies solely to inform decisions for interventions in physics education especially in developing countries like Uganda could be misleading.

Hence, with the overall aim of exploring the relationships between interest, motivation, and cognitive learning strategies use among lower secondary school students during Physics learning in Uganda, the present study contributes to physics education research in developing countries. In particular, the project aimed establishing an instrument with strong psychometric properties that could be used to assess physics learning motivation in lower secondary school. More so, changes in students motivation and learning strategies use across time and how they related with gender and autonomy support whilst using person-centered approaches were examined. Thus, four successive tasks emerged. Each of these tasks was addressed in an article.

3.1.1 Article 1

The first task of this study was to establish an instrument to assess physics learning motivation in lower secondary school students. As stated earlier in the introduction, there is a scarcity of research in physics education especially physics learning motivation (Ardura & Pérez-Bitrián, 2019; Kwarikunda et al., 2020). One of the reasons highlighted for the scarce research in physics motivation is the lack of instruments with strong psychometric properties to assess motivation as a multi-dimension construct (Ardura & Pérez-Bitrián, 2019), especially in lower secondary school students. Additionally, the existing instruments were grounded on other theories (Pintrich et al., 1991; Pintrich et al., 1993) in contrast to the theory grounding the present research. Studies that used the present study instrument accessed students' motivation in older students (e.g., Ardura & Pérez-Bitrián, 2019; Glynn & Koballa, 2006; Glynn et al., 2009)

In this thesis, an adaptation of the science motivation questionnaire was done. The science motivation questionnaire was chosen due to its broad inclusion of the several motivation constructs and proof of strong psychometric properties (as demonstrated in Ardura & Pérez-Bitrián, 2019; Glynn et al., 2011; Glynn & Koballa, 2006; Schumm & Bogner, 2016) . However, due to the difference in cultural context, domain, and age of participants in which this instrument was developed (see (Glynn et al., 2011)), we could not use it for the present study in its original form. Consequently, an adaptation and validation study was done as reported in chapter 4 of this thesis to assess the instrument fit for lower secondary school students. Additionally, little is known of the gender differences in physics learning motivation in lower secondary school students, and predictive effects of interest on students' motivation during physics learning. Thus, the first study was guided by three goals:

1. to adapt and validate the small to lower secondary school students motivation in Ugandan context.

2. to test whether the measure of physics learning motivation are invariant across gender and consequently access the gender differences in students' physics learning motivation.

3. to establish the extent to which students interest predicted their physics learning motivation.

Obtaining a valid instrument to assess physics learning motivation formed a foundation for subsequent tasks of this thesis as an attempt to close the wider knowledge gap within physics learning motivation research using lower secondary school students was done.

3.1.2 Article 2

After obtaining a tool fit to assess physics learning motivation in lower secondary school students, the second task of this thesis involved an investigation of the various combinations of motivation that lower secondary school students posses during physics learning. Theoretically, different individuals posses various drives for learning physics on assumption that students are motivated differently depending on varying psychosocial factors (Chittum & Jones, 2017; Pintrich & Zusho, 2002) For instance some students might be extrinsically motivated to obtain good physics grades whereas the other are extrinsically motivated to pursue a career in physics probably because of the rewards attached to the career. However, it is assumed that no student is purely intrinsically or extrinsically motivated (Chittum & Jones, 2017; Corpus & Wormington, 2014; Vansteenkiste et al., 2009). Rather, students tend to possess different levels and qualities of motivation depending on the task at hand. Empirically, evidence of the various combinations of motivation during physics learning is scarce and inconsistent (Vansteenkiste et al., 2009).

Of the several potential reasons for the contradicting findings include the motivational constructs used and the methodology used for examining the occurrence of the various patterns of students' motivation during physics learning(Vermunt, 2010; Wang & Wang, 2012). Hence, the second task of this study was a methodologically rigorous examination occurrence of various profiles of students depending on their combinations of motivation during physics learning. The choice to use L.P.A. was due to their methodological advantages over traditional cluster analyses like ***K***-means cluster analyses (Vermunt, 2010; Wang & Wang, 2012). Upon identifying the latent profiles, Wang and Wang, 2012 recommend external validating the identified profiles with variable within the theoretical frame used to interpret their meaning.

In this study, the various cognitive and metacognitive learning strategies were used to validate the profiles, given the relationship cognitive learning strategies use has with motivation (Obergriesser & Stoeger, 2020; Pintrich, 2003; Wolters & Pintrich, 1998). Differences between the various identified profiles in terms of cognitive and metacognitive strategy use were examined, on assumption that members in the high quality profile use deep-level learning skills. Results from such an examination inform of the various nature of strategies most students in that profile use, filling a domain-specific knowledge gap identified in (Bouckenooghe et al., 2016; Liu et al., 2014; Ning & Downing, 2015). More so, the predictive effects of genders, attitudes, and individual interest on the likelihood of members into various profiles is not known. The second article was guided by three specific goals:

1. to uncover the patterns of motivation that exists among lower secondary school students during physics learning
2. to access the differences in students' cognitive learning strategies in the identified profiles.
3. to access the predictive effects of gender, attitudes, and individual interest on the likelihood membership into the various profiles.

3.1.3 Article 3

Whereas the second article focused on identifying the various patterns of learners' physics motivation, in article 3, focus was on identifying the various combinations of cognitive and meta cognitive learning strategies used by lower secondary school students use during physics learning. Since physics is notated as a difficult to learn and abstract subject (Angell et al., 2004; Sidin, 2003) cognition and metacognition of the material learned is very crucial for positive learner outcomes. Lack of an adaptive cognitive and metacognitive repertoire could negatively affect students' academic progress, lifelong learning goals, and consequently career choice (Rogiers et al., 2019). A review of literature indicated that little is known of the various repertoire of cognitive and metacognitive learning strategies used during physics learning in lower secondary school students. More so, literature indicates existence of gender discrepancies in combinations of the cognitive and metacognitive strategy usage in other science subjects(e.g., Hong et al., 2020) However, little is known about learning strategies repertoire of lower secondary school physics students. Thus, the third task of this thesis was to document the occurrence of different student profiles based on their learning strategies use. consequently, article 3 was developed whose goals were three folded, that is:

1. to identify the distinct 8th grade learner profiles based on their various combinations of cognitive and metacognitive learning strategy use during physics learning.
2. to access the gender differences in cognitive and metacognitive strategy use in (9th during physics learning
3. to explore the relationship between autonomy support, intrinsic motivation and cognitive learning strategies use using a person-centered approach.

3.1.4 Article 4

Whereas Articles 3 and 4 focused on cross-sectional personal-centered analyses of students' physics learning motivation and learning strategy usage, the focus of manuscript two was to examine the longitudinal relations between students' physics motivation and cognitive learning strategy usage. As the final task of this thesis, focus was to access within- persons and within-sample stability in regard to students' physics learning motivation and their cognitive learning strategies. This was done to address the research knowledge gap that exists in terms of a track of students' motivation and cognitive learning strategy usage (Bouffard et al., 2003; Zhao & Qin, 2021), especially as they advance from one class to another in secondary school. Precisely, given that the change in students' motivation and cognitive learning strategies usage are complex beyond just an increase or decrease and domain specific (Bouffard et al., 2003;

Oga-Baldwin & Fryer, 2018; Xie et al., 2022), we used a person-centered approach- Latent profile transition analysis to examine the transition probability with-in and between motivation and cognitive learning strategy use profiles identified in article 2 and 3, respectively. More so, the predictive role of individual interest and perceived autonomy support during such profile membership transitions has not yet been examined. Thus, article 4 was guided by following hypotheses:

1. that the profiles' nature (except profile size) would be the same as in Kwarikunda et al. (2021) and Kwarikunda et al. (2022) for the motivation and (Meta) cognitive learning strategy use variables, respectively.

2. that the quality profiles were more stable than the quantity profile across time and thus, that there would be an increase in size of the quality profiles with time.

3. that higher levels of perceived autonomy support and individual interest increased transition membership likelihood into deep-level learner profile than the surface-level learner profile.

3.2 Methodology

In this section, a description of the sample, instruments used for data collection, and ethical procedures followed during data collection is done.

3.2.1 Sample

Masaka district comprises of 25 secondary schools with a total population of 6657 senior one and 7454 senior two students (District Education Office records, 2018). Krejice and Morgan (1978) tables for sample estimation recommend that a sample size of 386 should be selected from a study population of approximately 4000 students, hence, a minimum of 486 students were expected to be selected for each class. However that was not case given that the distribution of students in the different schools is not even. Some schools have more students (above 100 per class) whilst others have few students (less than 40). Thus, instead of concentrating on the number of students, emphasis was put on selecting schools for the study. Of the 25 schools, school headteachers from 9 schools did not provide the required consent and permission to allow their students participate in the study. Once a school headteacher provided consent, all the grade 8 students in that school were considered as potential participants for the study. Confirmation for participation in the study was only after provision of written consent after the information giving session.

Sampling strategy for schools.

Initially, the 16 schools were be placed into three strata depending on the source of funding which include: (a) fully government−funded schools, (b) partially government−funded schools, and (c)privately−owned schools. This was done to ensure that most students from the different social backgrounds were represented. Two schools were then randomly selected from each stratum. However, two strata - fully government−funded schools and privately-owned schools contained very many schools. One more school was selected from each of these two strata. Hence, a total of eight schools were chosen for the main study. Participants from the remaining eight schools that were not recruited for the main study were recruited for the pilot study.

Participants

Participants for the pilot study. 379 grade 8 students were recruited. However, Data from five female students were excluded from the study because these students did not sign the consent forms. Thus, data from 374 students was used in the analyses. Most of the students were 14 years old (SD = 1.59; range 13 – 19 years). The majority of the participants (206 students; 56%) were females. There were more day students (n = 194, 51%) than boarding students (n= 185, 49%).

Participants for the Main study at T1. 934 (56%) female and 411 (44%) male Grade 9 students were recruited for the main study. Five female and four male students did not sign the consent form and were thus eliminated from data analysis. The majority of participants were aged between 14 and 15 years (mean = 15, SD = 1.51), and resided at home (n = 475, 51%).

Participants for the Main study at T2. 534 grade 10 students participated in second phase of the study. Twenty eight of these students requested to participate in the second phase of the study although they did not participate in the first phase of the study. Thus, Data from these 28 students were eliminated for data analysis. Most of the students were 16 years old (Mean = 16.58, SD = 1.36) at time of data collection.

3.2.2 Measures

Data was collected using a questionnaire that comprised of six sections. the first section elicited students demographic characteristics such as gender, age and residence status of the participants. Gender was assessed on a binary basis that is male or female only. Students were provided with an open blank space were they could fill in their age. Residence status was also binary that is either day scholar or boarding student. Day scholars are those students who reside outside the school premises (including staff housing) whilst boarding students are those students that reside within the school premises.

Individual Interest

The second section of the questionnaire comprised of items which elicited students' individual interest in Physics learning. The Individual Interest Questionnaire (IIQ; Rotgans, 2015) was used. The scale consisted of 7 items e.g., "I am very interested in Physics". A full list of the items cam be found in Table6.6 The items were rated on a 5-point Likert scale, ranging from 1 (not true at all) to 5 (very true for me). No modification were made on the IIQ scale used in the present study.

Motivation

Students' motivation was assessed using the a modified 24-item Physics Motivation Questionnaire-II (PMQ-II;originally developed by (Glynn et al., 2011)). As reported in article 1, the Science motivation Questionnaire-II (SMQ-II) was not used as in its original form. Rather, several modifications were done to suit the study context. Firstly, the word 'Science' was replaced with 'Physics' in this entire section of the questionnaire. Replacing 'Science' with 'Physics' was done to contextualise the measure to physics domain. Examples of modified items include "I am confident i will do well in physics", "I enjoy learning physics among others (see Table6.2). Secondly, the word 'grade A' was replaced with ' marks between 80% and above' since at lower secondary level in Uganda grades are in percentages. Consequently, item 8 (it is important that I get marks between 80% in physics tests and exams) and item 18 (I believe I can get marks between 80% and above in physics tests and exams) were modified in this regard. Nevertheless, an equivalence of 'grade A' was maintained. Thirdly, all items related to students' physics motivation for physics achievement in which the word 'tests' was used, such items were modified by adding the word 'exams' . Much as the word 'tests' could be used for both formative and summative assessments in the US context(Glynn et al., 2011), in the present study's context, 'tests' is used only for formative assessment while 'exams' is used for summative assessment. Thus, to efficient assessment of the intended variables without altering the meaning of the items, the word ‘exams’ was added to the items 18, 16, 2, and 8. Lastly, items 14, 6, 24 were modified by adding ”experiments”, ”different”, and ”laboratory work” respectively. In these items, adding such words provided more clarity to the items, given that most students who read through the instrument before its validation raised issues of clarity on these items.

The physics version of the SMQ-II that was used contained five subscales that measured different dimensions of motivation; Intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation. The subscale intrinsic motivation contains items 01, 03, 12, 17, and 19 that requires students to report their enjoyment and curiosity during physics learning in and outside their classrooms. The items 05, 06, 11, 16, and 22 assessed students willingness to put extra effort in learning physics(self-determination). Students’ self-efficacy was assessed using items 09, 14, 15, 18, and 21. Last but not least, career motivation was assessed using items 07, 10, 13, 23, and 25. Students’ motivation to obtain good grades in physics than their peers was assessed using items 02, 04, 08, 20, and 24. Each of the five sub-scales originally comprised of five items (see Table 6.2) that were answered on a five-point Likert-scale ranging from 1 (never) to 5 (always). However, after the validation analysis (see Article 1), item (23) was deleted from the questionnaire. Consequently, career motivation was assessed using 4 items.

Cognitive and Metacognitive Learning Strategies

In the fourth section, different aspects of learning strategies were measured. The cognitive and metacognitive learning strategies section of the Motivated Strategies Learning Questionnaire (MSLQ; Pintrich et al., 1991) was used. The cognitive and metacognitive learning strategies section of the MSLQ were selected because it incorporates various categories of learning strategies. Specifically, rehearsal, elaboration, organisation, critical thinking, and metacognitive self-regulation strategies were assessed. Items were modified to suite the study context by replacing “class” with “Physics class”. An example of a modified rehearsal strategy item includes “I memorize key words to remind me of important concepts in the Physics class”. All items were answered on a 5-point Likert scale ranging from 7 (very true of me) to 1 (not at all true for me). Results of the confirmatory factor analysis on the five-factor model was assessed. Inter-factor correlations were also assessed.

Perceived Autonomy support

The fifth section assessed students’ perceived teacher autonomy support. A 15-item section of the Learning Climate Questionnaire Williams and Deci (1996) was used. The items were modified to fit the study context by including the word ”physics”. Examples of the sample items included “I feel that my physics teacher provides me choices and options” and “my physics teacher shows confidence in my ability to do well in physics tests”. The items were scored on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Following a confirmatory factor analysis, one item “I feel able to share my feelings with my physics teacher” had a factor loading less than 0.40. Consequently, this item was excluded. Fit indices are reported in Tables **??**.

Attitudes towards Physics learning

The last section of the questionnaire comprised of items that elicited for ratings of Students’ attitudes towards Physics learning. A 14-item subscale (Physics learning attitudes) section of the Physics Attitude Scale (PAS; Kaur & Zhao, 2017) was used. Items were scored on a five-point Likert scale with anchors ranging from strongly agree (5) to strongly disagree (1). An example of the items includes ‘I wait eagerly for the Physics period’.

3.2.3 Ethical Procedures

Initially, ethical clearance was sought from Mbarara University of Science and Technology-Research Ethical Committee (MUST-REC) which was granted as indicated in appendix. For legal reasons, ethical clearance was also obtained from the University of Potsdam Research ethical Commission (Appendix). School headteachers of the selected schools gave written consent and permission allowing us access to students and Physics teachers for data collection. In-depth discussions about the purpose, significance, and the data collection and protection procedures of the study were conducted during the information-giving session prior to data collection. Students were recruited without coercion. To attest to voluntary participation in the study, the provided written consent each time they were administered the questionnaire. The questionnaires were administered during one of the Physics classes in the presence of at least one of the researchers and a research assistant.Participants required approximately 30 minutes to complete the questionnaire. The participants were compensated for their time.

CHAPTER 4

ARTICLE 1

The Relationship between Motivation for, and Interest in, Learning Physics among Lower Secondary School Students in Uganda.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in Uganda. *African Journal of Research in Mathematics, Science and Technology Education, 24*(3), 435–446. DOI:10.1080/18117295.2020.1841961

Abstract

Motivation and interest affect students' learning especially in Physics, a subject learners perceive as abstract. The present study was guided by three objectives: (a) to adapt and validate the Science Motivation Questionnaire (SMQ-II) for the Ugandan context; (b) to examine whether there are significant differences in motivation for learning Physics with respect to students' gender; and (c) to establish the extent to which students' interest predicts their motivation to learn Physics. The sample comprised 374 randomly selected students from five schools in central Uganda who responded to anonymous questionnaires that included scales from the SMQ-II and the Individual Interest Questionnaire. Data were analysed using confirmatory factor analyses, t-tests and structural equation modelling in SPSS-25 and Mplus-8. The five-factor model solution of the SMQ-II fitted adequately with the present data, with deletion of one item. The modified SMQ-II exhibited invariant factor loadings and intercepts (i.e., strong measurement invariance) when administered to boys and girls. Furthermore, motivation for learning Physics did not vary with gender. Students' interest was related to motivation for learning Physics. Lastly, although students' interest significantly predicted all motivational constructs, we noted considerable predictive strength of interest on students' self-efficacy and self-determination in learning Physics. Implications of these findings for the teaching and learning of Physics at lower secondary school are discussed in the paper.

4.1 Introduction

In recent years, there has been a global outcry over the poor achievement of students in Science subjects (Keller et al., 2017) and especially Physics (Barmby et al., 2008; Oon and Subramaniam, 2011) at tertiary and secondary school levels. In addition, major concerns have been expressed about the rapid decrease in the number of students opting for Physics-oriented courses at tertiary institutions of learning (Osborne et al., 2003) in both developed and developing countries (Gudyanga et al., 2015). Uganda has had a rough share of this experience. For instance, for the last decade Physics has ranked as the worst performing subject in the final examination at secondary school level (UNEB, 2017).

Poor achievement in Physics is influenced by the students' motivation for and interest in learning Physics (e.g., Keller et al., 2017; Potvin & Hasni, 2014; Tuan et al., 2005). This lack of motivation and interest may interfere with the students' decision making and behaviour towards Physics learning, especially in girls (Schumm & Bogner, 2016). Yet little is known about motivation for and interest in learning Physics in Sub-Saharan Africa. In addition, there are no validated measures to assess students' motivation and interest. Thus there is need to develop instruments with sound psychometric properties to aid the assessment of students' motivation before appropriate interventions such as tailored teaching methods and programmes such as inquiry-based learning can be implemented and evaluated. Therefore the present study was conducted with three main objectives: (a) to adapt and validate the Science Motivation Questionnaire (SMQ-II) when used to assess motivation to learn Physics among secondary school students in the Ugandan context; (b) to examine significant differences in motivation for learning Physics with respect to students' gender; and (c) to establish the extent to which students' interest predicts their motivation to learn Physics.

4.1.1 Secondary School Physics Education in Uganda

At secondary school level, the Ugandan Physics curriculum is divided into two dimensions: (a) Ordinary secondary school curriculum – from 8 th to 11th years of formal schooling; and

(b) Advanced secondary school curriculum (from 12^{th} to 13^{th} years of formal schooling). With the interest in innovation and expansion in Science and Technology in the country, in 2005 the Ugandan government adopted the Compulsory Science Policy, in which all Science subjects including Physics were made compulsory from 8^{th} to 11^{th} year (Asiimwe, 2013). Following the pronouncement of the Compulsory Science Policy, various strategies and innovations have been put in place by the government to foster students' achievement in Science subjects. These among other things include the recruitment of more Science teachers and the construction of more Science laboratories.

However, in spite of the above-mentioned efforts by the Ugandan government, statistics from the Uganda National Examinations Board (UNEB) – the board responsible for national education evaluation and assessment – indicate that for the last decade Sciences has been the most poorly performing subject nationwide with Physics ranking as the worst performing overall at lower secondary school level (e.g. UNEB, 2017). For instance, in 2015, of the 303,237 students who sat for the Physics national exam, only 15.5% passed with credits and distinctions (marks between 40% and 100%), while in 2016, of 323,276 students, only 9.7% passed with credits and distinction. This implies that only 15.5% and 9.7% of the students were eligible to take Physics at Advanced level in the respective years. Several reports have attributed this poor achievement in Science to a number of factors such as: (a) low self-efficacy (Asiimwe, 2013); (b) poor learners' attitudes towards Science subjects (e.g., Potvin & Hasni, 2014); (c) the abstract nature of Science subjects (e.g., Kwarikunda et al., 2020; Saleh, 2014); and (d) failure of learners to relate Science subjects to real-life experiences (e.g., Kwesiga, 2002). However, to the best of our knowledge, no study has been conducted to assess students' motivation for and interest in learning physics.

4.1.2 Theoretical Framework

We grounded our study in the social-cognitive theory of learning (Bandura, 1986). In this framework, motivation to learn science is often defined as 'the internal state that arouses, directs and sustains science learning behavior' (Glynn et al., 2011, p. 1160). Motivation for science learning includes intrinsic motivation, self-determination, self-efficacy, goal motivation and career motivation. Intrinsic motivation is the drive students feel when they do something because it is inherently interesting and enjoyable (Ryan & Deci, 2000). Self-determination refers mostly to the effort and commitment students show in Physics classes (Schumm & Bogner, 2016). Self-efficacy is the individual's perception of competence to accomplish Physics tasks and attain certain results (Pajares, 1996). In a school setting, learners are motivated to achieve tangible outcomes. The learner outcomes can be short term such as Physics grades (grade motivation) or long term, for example, careers in Physics (career motivation).

Hidi and Renninger (2006) have conceptualised interest in science as 'both the state of heightened affect for Science and the predisposition to re-engage science again' (p. 114). In the context of physics, learners with high interest in learning Physics use a variety of adaptive learning strategies to achieve their set goals, and are highly self-regulated compared with their counterparts with low interest.

4.1.3 Differences in Motivation towards Science Learning between Boys and Girls

Previous studies have reported motivational differences that favour male students in learning of Science and Math among students at secondary school level (e.g., Meece & Jones, 1996), although other studies indicate the contrary (e.g., Ardura & Pérez-Bitrián, 2019; Opolot-Okurut, 2010). In Germany, Schumm and Bogner (2016) noted that there was no gender difference in intrinsic motivation, career motivation and overall motivation when they assessed the motivation of 232 tenth graders. However, gender differences existed in self-determination and self-efficacy with male students having lower scores compared with those of female students in self-determination. These findings were consistent with a study by Ardura and Pérez-Bitrián (2018) using a sample of Spanish students. Also in both studies, male students had higher scores of self-efficacy as compared with female students. These findings about higher efficacy and confidence beliefs among boys compared with girls have been supported in studies in various countries such as the USA (Britner & Pajares, 2001) and Uganda (Opolot-Okurut, 2010).

On the contrary, when Salta and Koulougliotis (2015) assessed students' motivation in 330 secondary school students in Greece, female students had significant higher scores on self-determination than the male students. Further, no gender differences were observed in students' self-efficacy. Rather, gender differences were noted in intrinsic motivation, with girls being more intrinsically motivated than boys.

Glynn et al. (2011) noted that boys had better motivational orientations towards Physical Sciences compared with girls whose motivational orientations were more inclined to Biological Sciences. Additionally, among low-ability Science students, boys tend to show higher mastery motivation compared with girls (Meece & Jones, 1996).

As discussed above, studies on the role of gender in students' motivation to learn Science and Physics have reported inconsistent findings. These studies seem to imply that this relation is context-dependent. In the Ugandan context, studies investigating motivation in Science learning at secondary school level have mainly been conducted in Mathematics (e.g., Opolot-Okurut, 2010), leaving a knowledge gap on the gender differences in motivation towards learning Physics. The present study, therefore, responds to the above research gap. Furthermore, findings from the present study will aid in developing interventions that are consistent with the students' gender motivational requirements.

4.1.4 Interest predicting students' Motivation for Learning Science

Previous studies have noted associations between students' interest and their related motivation for learning (e.g., Schiefele, 1991). As to whether interest predicts motivation or vice versa, there have been many controversies since interest is content and context related (Schiefele, 1991). Some studies have revealed that interest in science predicts motivation (e.g., Ardura & Pérez-Bitrián, 2019; Hidi & Renninger, 2006), while other studies indicate otherwise (e.g. Leaper et al., 2012). Further, some longitudinal studies indicate reciprocal prediction between interest and motivation (e.g., Niemivirta & Tapola, 2007). Hardly any research has been done to uncover the predictive relation between interest in, and motivation for learning Physics more specifically in developing countries like Uganda. Thus, the current study sought to uncover this relationship.

4.1.5 The Science Motivation Questionaire-II

The original 30-item SMQ developed in 2006 for college students by Glynn and Koballa (2006) had five subscales (i.e. intrinsic motivation, extrinsic motivation, personal relevance of Science learning, self-efficacy and anxiety about Science assessment) with each subscale comprising five items answered on a five-point Likert scale ranging from 1 (never) to 5 (always). However, upon conducting an exploratory factor analysis on the SMQ, results found the construct validity of the SMQ significantly wanting (Glynn et al., 2009). Based on the Classical Test theory, Glynn et al., 2011 revised the SMQ. Further validation studies by Glynn and colleagues in 2015 using a sample of 680 US undergraduate students indicated that the SMQ-II exhibited high construct validity and reliability when used within the US context.

However, Glynn and colleagues recommended further validation studies in different study contexts and Science disciplines for continued improvement of its construct validity in different settings. To this end, various researchers have adapted and validated the SMQ-II in different languages such as: (a) Greek (Salta & Koulougliotis, 2015); (b) German (Schumm & Bogner, 2016); and (c) Spanish (Ardura & Pérez-Bitrián, 2018). The SMQ-II has also been adapted and validated using several students populations such as secondary school students (Ardura & Pérez-Bitrián, 2018; Salta & Koulougliotis, 2015), and various subjects, such as Chemistry (e.g., Salta & Koulougliotis, 2015). The SMQ-II yielded different results when it was adapted and validated in different countries. For example, SMQ-II subscales yielded higher reliability coefficients (indicated by high Cronbach alphas) when used in Spain than when it was used in Greece, although in both countries it was used among high school students studying Chemistry. Also according to the subscale, intrinsic motivation was highest in the Greek sample compared with the Spanish group, where it was lowest.

In Germany, Schumm and Bogner (2016) revealed that two items (22 and 25) of the German version of the SMQ-II had lower loadings that deviated from the hypothesised model by Glynn et al. (2011) and colleagues, and consequently, these items were dropped, shortening the instrument further. Further inconsistent differences were noticed when comparing the findings of the German sample with those of the Spanish and Greek samples. In the Greek version, girls had higher self-determination, career motivation and intrinsic motivation than the boys, whereas, in the Spanish and German versions, girls only scored more highly on grade motivation than boys. Further, differences in measurement invariances, reliability and correlations within the components of motivation have been identified when the SMQ-II is used in different countries and study populations.

It is, therefore, important to validate this instrument to ascertain its psychometric soundness before it is used within any study population and context. Further, the above studies have been conducted in the American or European educational contexts which differ significantly from the Ugandan context under consideration in the present study. Therefore, we could not rely on the findings of validation studies from the above contexts to inform us about the fitness of the SMQ-II in the Ugandan context. Thus, we tested the instrument to determine whether it was fit for our target group in the Ugandan setting. Moreover, validation of the SMQ-II in the Ugandan context allows for cross-cultural comparisons on different motivational aspects between Ugandan students and those elsewhere.

4.2 Methods

4.2.1 Sample

Data were collected from five secondary schools (three in urban setting while two were in rural setting) located in Masaka district, Central Uganda, with a total number of approximately 1,580 students studying in Grade 8 of formal schooling. Within each school, all of the Grade 8 students present that day were given a questionnaire to fill in. We obtained data from 379 students from the above study population. Data from five female students were excluded because they did not sign the consent forms. In total, data from 374 students with the mean age of 14 years (SD = 1.59; range 13 – 19 years) were used for analyses. The majority of the participants (206 students; 56%) were females. There were more day students (n = 194, 51%) than boarding students (n= 185, 49%).

4.2.2 Procedure

Ethical approval for the study was obtained from Mbarara University of Science Technology, Research Ethics Committee. The study team visited the selected schools where they explained relevant details about the study to the school management as a way of eliciting their support. We had discussions with selected students where we explained the purpose of the study, the study objectives, sampling criteria and ethical considerations, among others. The students asked study-related questions that were responded to by the study team. Students who provided consent in addition to parental consent were enrolled to the study. Students took about 20–30 min to respond to the anonymised combined questionnaire.

4.2.3 Instrument

We elicited demographic characteristics like gender, age and residence status of the participants. Students' motivation was assessed using the 25-item SMQ-II (Glynn et al., 2011). We adapted the SMQ-II to our study purpose by replacing the word 'Science' with 'Physics'. Additionally, we replaced the word 'grade A' with 'between 75% and 100%' since at lower secondary level in Uganda, grades are in percentages. Each of the five sub-scales comprises five items (see Table 6.2) answered on a five-point Likert-scale ranging from 1 (never) to 5 (always).

The seven-item Individual Interest Questionnaire (IIQ) was developed and validated by Rotgans (2015). Items on the IIQ (see Table 4.5) are scored on a five-point Likert scale ranging from 1(not true at all) to 5 (very true for me). Average scores in range of 1–2 indicate low interest while average scores in the range 4-5 indicate high interest levels. Reliability coefficients for the scales used in the present study were acceptable and ranged between 0.66 and 0.78 (see Table 4.5). On validating the IIQ in the Ugandan context, the fit indices indicated that it was fit for the population used (comparative fit index, CFI = 0.965, Tucker–Lewis index, TLI = 0.948, root mean square error of approximation, RMSEA = 0.048 and standardised root mean square residual, SRMR = 0.036).

4.2.4 Data Analyses

Initially, data were screened for outliers, normality and missing values. No outliers were detected in our dataset. We noted that some items had missing values of $<0.5\%$, and these were handled by the full-information-maximum-likelihood method as it is more efficient compared with other techniques such as list-wise deletion (Usher & Pajares, 2009). Additionally, we screened the data set for its suitability for factor analysis using the Kaiser–Meyer–Olkin measure of sampling adequacy and the Bartlett's test of sphericity. These initial analyses were conducted in SPSS-25. Our data passed both tests (Kaiser-Meyer-Olkin = 0.93; Bartlett's test of sphericity, χ^2 = 2571.65, d.f. = 276, $p < 0.05$), indicating that the correlation matrix of items was of adequate quality. After ascertaining the suitability of the data for factor analysis, we randomly split our sample into two groups (n_1 = 196, n_2 = 178) for confirmatory factor analysis (CFA). We selected CFA because: (a) our study aimed at testing the five-factor model proposed by Glynn et al. (2011) to physics learning; (b) CFA provides a rigorous test of equivalence across the groups (Salta & Koulougliotis, 2015); and (c) CFA is preferred when measurement models have strong hypotheses regarding the number of latent variables in the model (Usher & Pajares, 2009). Subsequently, using the whole sample, a multigroup CFA in order to examine whether the items' factor loadings and intercepts are invariant across female and male participants was conducted before conducting mean comparisons in the subsequent steps. t-Tests were used to analyse differences between motivation to learn Physics and gender.

Lastly, before running the prediction model, we conducted Pearson's correlation coefficient analyses between the motivational components and students' interest to learn Physics in order to determine associations between these variables. We then assessed the measurement model to examine its suitability in estimating the structural model in the subsequent phase. After obtaining a perfectly fitting model, a structural model was estimated. Model estimations were conducted using Mplus 8 (Muthén & Muthen, 2017). Model fit evaluations during CFAs and structural models were based on model fit indices including the CFI, TLI, RMSEA and SRMR. A combination of the above fit indices minimises Type I and Type II errors (Hu & Bentler, 1999). We followed the model fit criteria suggested by Hu and Bentler (1999) that includes CFI and TLI values $\geq$ 0.90, SRMR $\leq$ 0.08 and RMSEA $\leq$ 0.06.

4.3 Results

4.3.1 Confirmatory Factor Analysis

After deleting item 'My career or job will involve physics' owing to very high correlation with the item 'I will use physics problem solving skills in my career' in prior analyses, the five-factor model structure fitted adequately with the present data since all of the above fit indices were within acceptable ranges for both validation samples (see Table 4.1) – providing evidence of construct validity of the modified version of the SMQ-II. The factor loadings were all above the acceptable value (see Table **??**).

Table 4.1

Summary of Goodness-of- Fit Statistics

	Sample size	Chi square value	CFI	TLI	RMSEA	SRMR
Sample 1	196	320.84	0.93	0.92	0.06	0.04
Sample 2	178	316.16	0.92	0.91	0.06	0.04

Table 4.2

SMQ-II Physics Version: Items and Factor Loadings Resulting from Confirmatory Factor Analyses on the two Separate Samples

Item number	Item statement	Factor loadings	
	Sample 1	Sample 2	
factor 1: Self-efficacy			
9	I am confident I will do well on physics tests	0.59	0.66
14	I am confident I will do well on physics experiments	0.66	0.62
15	I believe I can master physics knowledge and skills	0.69	0.68
18	I believe I can get marks between 75% and 100% in physics tests and exams	0.60	0.58
21	I am sure I can understand physics	0.68	0.63
Factor 2: Self-determination			
5	I put enough effort into learning physics	0.58	0.5
6	I use different strategies to learn physics	0.46	0.51
11	I spend a lot of time learning physics	0.50	0.56
16	I prepare well for physics tests and practicals	0.58	0.57
22	I study hard to learn physics	0.61	0.53
Factor 3: Intrinsic motivation			
1	The physics I learn is relevant to my life	0.48	0.51
3	Learning physics is interesting	0.54	0.61
12	Learning physics makes my life more meaning full	0.55	0.60
17	I am curious about discoveries in physics	0.51	0.52
19	I enjoy learning physics	0.69	0.72
Factor 4: Career motivation			
7	Learning physics will help me get a good job	0.68	0.66
10	Knowing physics will give me a job advantage.	0.74	0.72
13	Understanding physics will benefit me in my career	0.70	0.64
25	I will use physics problem solving skills in my career	0.52	0.43
23	My career or job will involve physics	-	-

Item number	Item statement	Factor loadings	
		Sample 1	Sample 2
Factor 5: Grade motivation			
2	I like to do better than other students on physics tests	0.60	0.53
4	Getting a good science grade is important to me	0.56	0.62
8	It is important that I get marks between 75% and 100% in physics tests/ exams	0.55	0.51
20	I think about the grade I will get in physics	0.47	0.49
24	Scoring high on physics tests and laboratory work matter to me a lot	0.55	0.53

4.3.2 Gender Differences in Motivation to Physics Learning

Before we proceeded to assess the differences in motivational components with gender, we first examined measurement invariance of the instrument among boys and girls to ascertain whether boys and girls interpreted the items of the Physics version of the SMQ-II in a similar way. As indicated in Table 4.3, the instrument demonstrated strong measurement invariance; hence, mean comparisons based on student gender could be carried out in the next steps.

Table 4.3

Tests of Invariance of the Physics Version of SMQ-II across Gender

	CFI	TLI	RMSEA	SRMR	ΔCFI
Girls	0.98	0.97	0.05	0.02	-
Boys	0.92	0.91	0.06	0.05	-
Configural invariance	0.95	0.94	0.06	0.03	-
Weak invariance	0.95	0.95	0.06	0.03	0.00
Strong invariance	0.96	0.95	0.06	0.03	0.01

There were no statistically significant differences for gender in students' motivation for physics learning (see Table 4.4). Nevertheless, female students scored slightly higher on all motivational components compared with male students. Generally, the mean score of students' intrinsic motivation towards Physics learning was lowest while their mean score of grade motivation was highest of the motivational components for both boys and girls.

4.3.3 Prediction of Students' Motivation to Learn Physics

Preliminary Results

Results indicated significant positive correlations between the study variables (see Table 4.5). We also noted that self-efficacy had stronger correlations with other components of motivation (r ranging between 0.56 and 0.65, $p < 0.01$). The results of correlations (see Table 6.6) indicated that interest could be used to predict students' motivation for learning Physics.

Table 4.4

Descriptive Statistics of the Physics Version of the SMQ-II Scales

Variable	Sex	N	M (SD)	t-statistic	p-value
Self-efficacy	Male	165	2.91 (0.86)	-0.60	0.55
	Female	209	2.96 (0.80)		
Self-determination	Male	165	2.71 (0.79)	-0.05	0.96
	Female	209	2.72 (0.73)		
Intrinsic motivation	Male	165	2.53 (0.91)	-0.29	0.77
	Female	209	2.55 (0.79)		
Career motivation	Male	165	2.93 (0.92)	-0.11	0.92
	Female	209	2.94 (0.89)		
Grade motivation	Male	165	3.12 (0.75)	-0.43	0.67
	Female	209	3.14 (0.72)		

Testing the Measurement Model

The measurement model fitted adequately with the data as indicated by the acceptable fit indices (CFI = 0.92, TLI = 0.91, SRMR = 0.05, RMSEA = 0.04). Factor loadings were also adequate since values were above 0.40 (see Tables 6.2 and 6.6).

Table 4.5

Descriptive statistics, correlations and reliability coefficients of the study variables

Variable	M (SD)	1.	2.	3.	4.	5.	6.	α
Interest	2.39 (0.80)	-	**0.41****	**0.50****	**0.55****	**0.41****	**0.32****	0.74
Self-efficacy	2.94 (0.83)		-	**0.56****	**0.61****	**0.62****	**0.65****	0.78
Self-determination	2.72 (0.76)			-	**0.61****	**0.49****	**0.53****	0.68
Intrinsic motivation	2.54 (0.84)				-	**0.55****	**0.53****	0.70
Career motivation	2.94 (0.90)					-	**0.54****	0.72
Grade motivation	3.13 (0.73)						-	0.66

Table 4.6

Items and Factor Loadings resulting from Confirmatory Factor Analysis on the Measurement Model containing SMQ-II and IIQ before Linear Regressions using the whole Selected Sample

Item number	Item statement	Factor loadings
factor 1: Self-efficacy		
9	I am confident I will do well on physics tests	0.63
14	I am confident I will do well on physics experiments	0.64
15	I believe I can master physics knowledge and skills	0.69
18	I believe I can get marks between 75% and 100% in physics tests and exams	0.59
21	I am sure I can understand physics	0.65
Factor 2: Self-determination		
5	I put enough effort into learning physics	0.53
6	I use different strategies to learn physics	0.48
11	I spend a lot of time learning physics	0.54
16	I prepare well for physics tests and practicals	0.58
22	I study hard to learn physics	0.65
Factor 3: Intrinsic motivation		
1	The physics I learn is relevant to my life	0.49
3	Learning physics is interesting	0.56
12	Learning physics makes my life more meaning full	0.58
17	I am curious about discoveries in physics	0.51
19	I enjoy learning physics	072
Factor 4: Career motivation		
7	Learning physics will help me get a good job	0.66
10	Knowing physics will give me a job advantage.	0.73
13	Understanding physics will benefit me in my career	0.67
25	I will use physics problem solving skills in my career	0.49
23	My career or job will involve physics	-

Item number	Item statement	Factor loadings
Factor 5: Grade motivation		
2	I like to do better than other students on physics tests	0.55
4	Getting a good science grade is important to me	0.58
8	It is important that I get marks between 75% and 100% in physics tests/ exams	0.53
20	I think about the grade I will get in physics	0.48
24	Scoring high on physics tests and laboratory work matter to me a lot	0.55
Prediction variable: Individual interest		
1	I am very interested in physics	0.69
2	Outside of school, I read a lot about physics	0.60
3	I always look forward to my physics lessons	0.68
4	I am interested in physics since I was young	0.52
5	I watch a lot of physics related TV channels like discovery channel	0.44
6	Later in my life I want to pursue a career in physics or physics related discipline for example doctors, engineers, teachers	0.47
7	When I am reading something about physics or watching something about physics on TV I am fully focused and at times I forget everything around me.	0.41

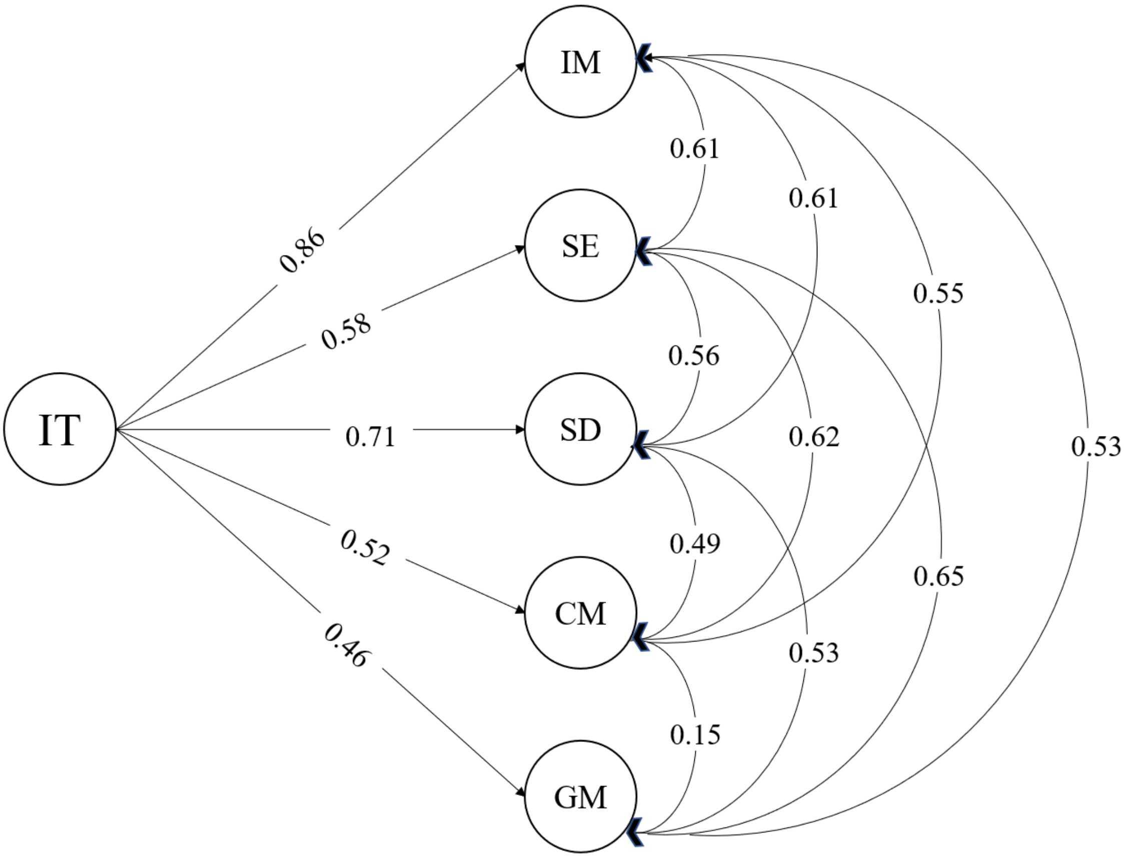
The Structural Model

The model fitted with the data adequately (CFI = 0.92, TLI = 0.91, SRMR = 0.05, RMSEA = 0.04). In this model, students' interest significantly predicted all of the indicators of students' motivation towards learning Physics including intrinsic motivation ($\beta_{standardised}$ = 0.80, p <0.001; R^2 = 0.644), self-efficacy ($\beta_{standardised}$ = 0.58, p < 0.001; R^2 = 0.338), self-determination ($\beta_{standardised}$ = 0.71, p < 0.001; R^2 = 0.505), career motivation

($\beta_{standardised}$= 0.52, $p < 0.001$; R^2 = 0.275) and grade motivation ($\beta_{standardised}$ = 0.46, p <0.001; R^2 = 0.212). As shown in Figure 4.1, interest showed very stronger contributions and explained more variance in students' intrinsic motivation and self-determination compared with other motivational variables.

Figure 4.1

Regression model showing the weights of interest for each sub-scale of motivation.



***Note*.** IT, Interest; IM, intrinsic motivation; SE, self-efficacy; SD, self-determination; CM, career motivation; GM, grade motivation.

4.4 Discussion

Adaptation and validation of an existing instrument enables cross-cultural comparisons and interpretation of results (Ardura & Pérez-Bitrián, 2018). We adapted and validated the SMQ-II using CFAs to test the five-component structure proposed by Glynn et al. (2011) and our findings provided evidence supporting the measure construct validity. The findings also confirmed fit for the Ugandan Physics version of the SMQ-II. This opens up the possibility of a reliable measurement of students' motivation to Physics learning within the Ugandan context and for reliable cross-cultural comparisons of the students' motivation.

Previous studies (e.g., Meece & Jones, 1996)) have indicated a significant gender difference in students' motivation to learn science – with most studies reporting higher motivation for males. However, in our study there were no statistically significant differences obtained between gender for the components of motivation. Jaen and Baccay (2016) also noted no significant gender differences in students' motivation for mathematics learning. Our findings, in part, reveal that female secondary school students are equally motivated to learn Physics just like their male counterparts in lower secondary school in Uganda. Interestingly, our analyses revealed that grade motivation was the most highly scored motivation trait, unlike intrinsic motivation, which scored the lowest. Findings using Greek (Salta & Koulougliotis, 2015), German (Schumm & Bogner, 2016) and Spanish (Ardura & Pérez-Bitrián, 2018) samples indicate a similar trend. For the Ugandan context, this finding is possibly an indicator that students may just want to pass the subject with relatively good grades. More so, the Ugandan Mathematics and Science curricula are overloaded with content. This poses major difficulties for teachers who resort to teacher-centred approaches (Opolot-Okurut, 2010) that emphasise motivation of their students towards obtaining higher grades (as indicated by the high scores of grade motivation). This extrinsic motivation towards grades has a detrimental effect on students' intrinsic motivation (see Potvin & Hasni, 2014).

Interest predicted students' motivation to learn Physics in Uganda. More specifically, interest explained more variance in intrinsic motivation and self-determination as compared with other motivational variables that we assessed. Our findings are in line with those of Bye et al. (2007). Usually, interest is the driving force behind intrinsic motivation (Schiefele, 1991), with a motivated student likely to display autonomy and employ self-initiated exploratory strategies (Schiefele, 1991), unlike uninterested students who rely on extrinsic motivation and instructions from the teachers as they seek external signs of work. Consequently, the uninterested learners cannot self-regulate their learning, which may result in low achievement in Physics.

4.4.1 Educational Implications

Since one of the postulated reasons for poor performance in Physics is the students' lack of motivation (González et al., 2017), there has been a lack of valid and reliable instruments to measure lower secondary school students' motivation to Physics learning. With our Physics version of the SMQ-II, other researchers in the region can adapt it to measure students' motivational traits and later if necessary design interventions that can result in improvement in Physics achievement. While taking into consideration suggestions made by Komperda et al. (2020), teachers and other researchers can use the instrument as a diagnostic tool after early identification of students' motivation levels. Intrinsic motivation and self-determination were the lowest scores in our sample. Since self-determination is not usually taught in schools (Potvin and Hasni, 2014), it would be a wise decision for schools to shift from teacher-centred to student-oriented approaches during the teaching-learning process. This will provide support for learners' autonomy which in turn will increase their self-determination and regulation (Zamora & Ardura, 2014).

The role of interest in Physics learning has been clearly shown in our study. Interest does not only predict learner motivation to Physics learning, but also explains the variance in intrinsic motivation and self-determination. The low intrinsic motivation and self-determination in our sample is indicative of how low levels of interest among students impact their learning of Physics. To improve learners' motivation, it is important for teachers to trigger the learners' curiosity, enthusiasm and enjoyment, as well as support their autonomy. This can be done by use of teaching methods such as guided inquiry Science teaching that has been found to positively affect learners' interest (Wolf & Fraser, 2008) and in turn motivate them towards Science learning (see Kang & Keinonen, 2018; Ramnarain, 2014).

4.5 Limitations

First, questionnaires were used to collect data. Such self-report measures are prone to bias and social desirability (Rotgans, 2015). Future studies can employ a mixed-methods approach. Secondly, the SMQ-II had low reliabilities as compared with other studies we reviewed (see the section 4.1.5). This could be due to the nature of the schools (semi-rural) we selected as compared with those used in the other studies we reviewed.

4.6 Conclusions

Firstly, the Physics version of the SMQ-II has been proven valid for lower secondary school students in Uganda. Therefore, this presents a valid instrument that can be used for measuring students' motivational traits to Physics learning. Secondly, there were no statistically significant relationships between gender and motivational levels towards Physics learning. Thirdly, lower secondary school students have low intrinsic motivation and high grade motivation. Lastly, interest predicts motivation to Physics learning. It is very important for educators to arouse the interest of learners if they are to improve on their motivation, and consequently their achievement in Physics.

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References

Ardura, D., & Pérez-Bitrián, A. (2018). The effect of motivation on the choice of chemistry in secondary schools: Adaptation and validation of the science motivation questionnaire ii to spanish students. *Chemistry Education Research and Practice*, *19*(3), 905–918.

Ardura, D., & Pérez-Bitrián, A. (2019). Motivational pathways towards academic achievement in physics & chemistry: A comparison between students who opt out and those who persist. *Chemistry education research and practice*, *20*(3), 618–632.

Asiimwe, J. A. (2013). Compulsory science policy: Enhancing gender equality in education? a case study of academic achievement in uganda. *MIER Journal of Educational Studies Trends and Practices*, 183–194.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*(23-28).

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International journal of science education*, *30*(8), 1075–1093.

Britner, S. L., & Pajares, F. (2001). Self-efficacy beliefs, motivation, race, and gender in middle school science. *Journal of women and Minorities in Science and Engineering*, *7*(4).

Bye, D., Pushkar, D., & Conway, M. (2007). Motivation, interest, and positive affect in traditional and nontraditional undergraduate students. *Adult education quarterly*, *57*(2), 141–158.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire ii: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159–1176.

Glynn, S., & Koballa, T. (2006). Motivation to learn in college science (p. 25-32). *J. J. Mintzes & WH Leonard (Eds.), Handbook of college science teaching. Arlington, VA: NSTA Press*.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(2), 127–146.

González, A., Fernández, M.-V. C., & Paoloni, P.-V. (2017). Hope and anxiety in physics class: Exploring their motivational antecedents and influence on metacognition and performance. *Journal of Research in Science Teaching*, *54*(5), 558–585.

Gudyanga, A., Adam, K., & Kurup, R. (2015). Zimbabwean female participation in physics: The influence of context on identity formation. *African Journal of Research in Mathematics, Science and Technology Education*, *19*(2), 172–184.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, *41*(2), 111–127.

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1–55.

Jaen, M. C. A., & Baccay, E. S. (2016). Curiosity, motivation, attitude, gender, and mathematics performance. *The Normal Lights*, *10*(2).

Kang, J., & Keinonen, T. (2018). The effect of student-centered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in science education*, *48*(4), 865–885.

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, *54*(5), 586–614.

Komperda, R., Hosbein, K. N., Phillips, M. M., & Barbera, J. (2020). Investigation of evidence for the internal structure of a modified science motivation questionnaire ii (msmq ii):

A failed attempt to improve instrument functioning across course, subject, and wording variants. *Chemistry Education Research and Practice*, *21*(3), 893–907.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in uganda. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 435–446.

Kwesiga, J. C. (2002). *Women's access to higher education in uganda: Uganda's experience.* Fountain Publishers Limited.

Leaper, C., Farkas, T., & Brown, C. S. (2012). Adolescent girls' experiences and gender-related beliefs in relation to their motivation in math/science and english. *Journal of youth and adolescence*, *41*(3), 268–282.

Meece, J. L., & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *33*(4), 393–406.

Muthén, L. K., & Muthen, B. (2017). *Mplus user's guide: Statistical analysis with latent variables, user's guide*. Muthén & Muthén.

Niemivirta, M., & Tapola, A. (2007). Self-efficacy, interest, and task performance: Within-task changes, mutual relationships, and predictive effects. *Zeitschrift für Pädagogische Psychologie*, *21*(3/4), 241–250.

Oon, P.-T., & Subramaniam, R. (2011). On the declining interest in physics among students—from the perspective of teachers. *International journal of Science education*, *33*(5), 727–746.

Opolot-Okurut, C. (2010). Classroom learning environment and motivation towards mathematics among secondary school students in uganda. *Learning Environments Research*, *13*(3), 267–277.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International journal of science education*, *25*(9), 1049–1079.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of educational research*, *66*(4), 543–578.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: A systematic review of 12 years of educational research. *Studies in science education*, *50*(1), 85–129.

Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in south africa. *Teaching and teacher education*, *38*, 65–75.

Rotgans, J. I. (2015). Validation study of a general subject-matter interest measure: The individual interest questionnaire (iiq). *Health Professions Education*, *1*(1), 67–75.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, *55*(1), 68.

Saleh, S. (2014). Malaysian students' motivation towards physics learning. *European Journal of Science and Mathematics Education*, *2*(4), 223–232.

Salta, K., & Koulougliotis, D. (2015). Assessing motivation to learn chemistry: Adaptation and validation of science motivation questionnaire ii with greek secondary school students. *Chemistry Education Research and Practice*, *16*(2), 237–250.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299–323.

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education*, *38*(3), 434–449.

Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International journal of science education*, *27*(6), 639–654.

UNEB. (2017). Statement of release of 2017 uce examination results. https://uneb.ac.ug/

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary educational psychology*, *34*(1), 89–101.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in science education*, *38*(3), 321–341.

Zamora, A., & Ardura, D. (2014). To what extent do high school physics students use their own mistakes to learn? an experience on self-regulation in a secondary school classroom. *Ensenanza de las Ciencias*, *32*(2), 253–268.

CHAPTER 5

ARTICLE 2

Secondary School Students' Motivation Profiles for Physics Learning: Relations with Cognitive Learning Strategies, Gender, Attitudes and Individual Interest

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). Secondary school students' motivation profiles for physics learning: relations with cognitive learning strategies, gender, attitudes and individual interest. *African Journal of Research in Mathematics, Science and Technology Education, 25*(2), 197–210. DOI:10.1080/18117295.2021.1956720

Abstract

For efficient and effective pedagogical interventions to address Uganda's alarmingly poor performance in Physics, it is vital to understand students' motivation patterns for Physics learning. Latent profile analysis (LPA) - a person-centred approach can be used to investigate these motivation patterns. Using a three-step approach to LPA, we sought to answer the following research questions: RQ1, which profiles of secondary school students exist with regards to their motivation for Physics learning; RQ2, are there differences in students' cognitive learning strategies in the identified profiles; and RQ3, does students'gender, attitudes, and individual interest predict membership in these profiles? The sample comprised 934 Grade 9 students from eight secondary schools in Uganda. Data were collected using standard is ed questionnaires. Six motivational profiles were identified: (i) low-quantity motivation profile (101 students; 10.8%); (ii) moderate-quantity motivation profile (246 students; 26.3%); (iii) high-quantity motivation profile (365 students; 39.1%); (iv) primarily intrinsically motivated profile (60 students,6.4%); (v) mostly extrinsically motivated profile (88 students, 9.4%); and (vi) grade-introjected profile(74 students, 7.9%). Low-quantity and grade introjected motivated students mostly used surface learning strategies whilst the high-quantity and primarily intrinsically motivated students used deep learning strategies. Lastly, unlike gender, individual interest and students' attitudes towards Physics learning predicted profile membership. Teachers should provide an interesting autonomous Physics classroom climate and give students clear instructions in self-reliant behaviours that promote intrinsic motivation.

5.1 Introduction

For the past decade, students in Uganda have performed poorly in Science subjects, especially Physics (UNEB, 2017). Consequently, the number of students willing to take Physics at advanced and tertiary levels has been rapidly decreasing (Kwarikunda et al., 2020), running counter to Uganda's projections of an accelerating need for improved. Science literacy and competitiveness in Science and Technology among its citizens. Before designing any pedagogical interventions to increase the uptake of Physics, there is an urgent need to fully understand students' motivation to learn Physics in Uganda.

To fully characterise and understand the learning process, theories have emphasised the differences in learners' knowledge, beliefs, motivation, strategies and abilities at specific points in time during the learning process (Hickendorff et al., 2018). In order to account for the differences in motivation (Lazarides et al., 2016), a significant amount of research has been done (e.g., Ardura & Pérez-Bitrián, 2019; Potvin & Hasni, 2014; Schumm & Bogner, 2016). These studies have mostly used variable-centered approaches (VCAs). VCAs assume that the relation between the constructs of motivation can be applied to all learners without catering for their individual differences (Vansteenkiste et al., 2009). They lack the ability to deal with heterogeneity within and between individuals. Specifically, numerous studies have explored students' motivation to learn Science using VCAs (e.g., Green et al., 2007). These studies have either treated Science as a whole (e.g. Zeyer, 2010) or have explored specific domains such as Chemistry (e.g., Ardura & Pérez-Bitrián, 2019) and Mathematics (Green et al., 2007). Whilst numerous studies have been conducted in developed countries and at university level, only a handful have investigated students' motivation for learning at secondary school level (e.g., Ardura & Pérez-Bitrián, 2019) in developing countries (e.g., Kwarikunda et al., 2020).

Conversely, person-centred analyses (e.g., latent profile analysis) primarily aim to categorise individuals into groups; members have similar profiles that remain concealed in VCAs. Latent profile analysis is a mixture modelling technique that employs a person-centred approach to uncover different existing but unobserved homogeneous subgroups of individuals (latent profiles) underlying a heterogeneous group (Wang & Wang, 2012). Unlike the traditional cluster analyses, e.g., K-means cluster analysis, which divide data into groups by measuring the Euclidean distance between the data points,latent profile analysis (LPA) uses probabilistic modelling to identify the likely groups and place individuals within these identified groups (Vermunt, 2010). LPA places emphasis on the individuals based on their patterns of individual characteristics, providing a moderate amount of parsimony and specificity (Muwonge et al., 2020). Latent profiles are formed such that there is much similarity within a profile,while at the same time as much difference between the profiles as possible (Hickendorff et al., 2018).Using LPA the dynamic interplay of latent profile indicator variables (in this case motivation) and covariates (like interest and attitudes) can be further studied at the individual level. Moreover, further insight into the complex ways in which other covariates interact with the motivational profiles that could have remained masked in VCA is provided by LPA (Vansteenkiste et al., 2009). Such insight snot only complement existing variable-centred motivation research (e.g., Kwarikunda et al., 2020), but also provide useful heuristics for understanding how these covariates associate with these particular latent profiles.

Watt et al. (2019) suggest that targeting a well-defined profile of students is more effective compared with targeting each individual in a classroom, since feedback can be easily individualised and instructional approaches are flexibly adapted to cater for a group of similar students rather than each individual. However, little work has been devoted to the person-centred approach by motivational researchers (Chittum & Jones, 2017; Vansteenkiste et al., 2009), especially in developing countries. Equally, research investigating the relationship between secondary school students' motivation and cognitive learning strategies during Physics learning in third world countries is very scarce. Thus, there is a need for further investigation of students' motivation for Physics learning using a person centred approach to (i) uncover the groups of students with distinct motivational profiles for Physics learning and their differing cognitive learning strategy uses that would otherwise have remained undetected in a VCA and (ii) provide further insights into possible ways in which gender, attitudes and individual interest influence membership of the disparate profiles in developing countries such as Uganda. Additionally, person centred methods provide a more nuanced understanding of the motivational dynamics associated with particular students' profiles (Watt et al., 2019), which is currently unknown in Physics education research. In the present study, we addressed this knowledge gap by identifying secondary school students' Physics learning motivational profiles using LPA (RQ1). Further, how students in the various motivational profiles differed in their cognitive learning strategy use (RQ2) was explored. Furthermore, the factors that predicted profile membership were investigated. Specifically, we investigated whether students' gender, attitude and individual interest predict membership in the above identified profiles (RQ3). Gaining insight into students' motivational profiles for Physics learning is fundamental, so that motivational interventions can be tailored to each particular profile.

5.2 Motivation

Cognitive Strategies, Individual Interests and Attitudes towards Science Learning.The study of students' Science learning through concepts such as motivation, individual interest and attitudes has been a major concern for researchers and educational systems around the world for quite some time (Potvin & Hasni, 2014). Although students' motivation for, individual interests and attitudes towards Science are sometimes judged to be generally positive (Potvin & Hasni, 2014), there have been reports of considerable international and contextual differences (e.g., Sjøberg & Schreiner, 2010), gender differences mostly in favour of males (Meece, 1996) and subject-related differences (Green et al., 2007).

As a complex multidimensional construct, motivation interacts with cognition to influence learning Science (Glynn et al., 2011). Although different learning theorists have attempted to describe motivation and its constructs, the social cognitive perspective provides a comprehensive framework that has influenced many Science learning studies to date. In this framework, motivation for learning Science is defined as the internal state that arouses, directs and sustains Science learning behaviour (Bandura, 1986; Glynn et al., 2011). Social cognitive theory outlines four constructs of motivation: self-efficacy, self-determination, intrinsic motivation and extrinsic motivation. Students who are motivated to learn Science are self-determined, maintain their interest and pay attention during the learning process

(Renninger, 2000), make an extra effort to learn (Potvin & Hasni, 2014) and use adaptive cognitive learning strategies (such as metacognition and critical thinking) that promote deep learning (Schiefele, 1991) to complete the learning task with high standards and excellence (Potvin and Hasni, 2014). Students who use maladaptive cognitive learning strategies, e.g., rehearsal (for memorisation) use strategies that result in surface learning, have low motivation for learning, and are more likely to achieve less during Physics classes (Schiefele, 1999).

On the other hand, given that individual interest is content specific, in Physics learning we refer to it as an enduring directive force that drives the ongoing feelings and deepening relations of a person to Physics (Renninger, 2000). Individual interest facilitates sustained attention and effort during learning, maintains enjoyment of focused and continued engagement in a task for the sake of the task itself and enhances the desire for mastery (Schiefele, 1999). Learners with high individual inter-est for learning Physics report high levels of intrinsic motivation, use a variety of adaptive cognitive learning strategies, highly endure during difficult learning tasks and are highly self-regulated com-pared with their counterparts with low interest (Kwarikunda et al., 2020). Individual interest increases as knowledge and the accompanying value (grade or career motivation) for the subject increase (Schiefele, 1991).

There has been little consensus in defining the term ‘attitudes’ among Science education researchers. However, in our study we adapted the definition offered by Keller et al. (2017), who described attitudes towards Physics as the feelings the student has about Physics learning based on their beliefs about Physics. Prior research (Potvin & Hasni, 2014) indicated that students with positive attitudes towards learning enjoy learning the subject with more confidence while using adaptive learning strategies. Attitudes have been found to greatly influence achievement. However, little is known about the relations between these variables during Physics learning in Uganda while using a person-centred approach. In the following section, we briefly provide an insight into results of studies that used a person-centred approach, in particular the LPA.

5.2.1 Previous studies using Latent Profile Analyses for Students' Motivation

Most motivation psychologists, parents and teachers agree that students' learning behaviours in Science disciplines differ from one student to another (Hickendorff et al., 2018) and across the various Science disciplines (Glynn et al., 2011). Mostly, these differences are a result of the multiple reasons that drive students' learning behaviours. Whilst particular motives may be of great importance to some students, the same motives may be less important to others, indicating that there might exist different groups of students characterised by different motivational profile.

Compared with cluster analyses, LPAs are based on a number of statistical indices and tests upon which the number of profiles can be identified (Muwonge et al., 2020). This reduces biases and subjectivity, which are common in cluster analyses (Wang & Wang, 2012). Despite little prior attention having been given to person-centred analyses by motivation researchers (Vansteenkiste et al., 2009), a few existing studies indicate that different profiles of students' motivation for Science learning exist. Below we summarise some of these studies.

Vansteenkiste et al. (2009) used a person-centred approach to identify motivation profiles of 881 grade 12 students from two secondary schools in Belgium. They used autonomous motivation and controlled motivation as the LPA indicators. Four profiles (good quality, good quantity, poor quality and poor quantity) were uncovered. Students in the good quality motivation profile (i.e., high autonomous, low controlled) scored highly on cognitive processing and achievement tests, unlike their peers in the poor-quality motivation profile. Similarly, Lazarides et al. (2016) used LPA and identified four motivational profiles in Mathematics using 849 Grade 7–12 students in Berlin, Germany. The researchers named these four profiles: low motivation profile, moderate motivation profile, utility motivation profile and high motivation profile. Students within the utility- and low-motivation profiles reported lower achievement in Mathematics than the students within other profiles.

Elsewhere in USA, whilst using intrinsic and extrinsic motivation as LPA variables, Hayenga and Corpus (2010) identified four Science motivational profiles using 343 Grade 7 and 8 students from public schools. They identified these profiles as: high-quality, low-quality, high-quantity and low-quantity motivation. The high-quality motivation profile consisted of students who achieved significantly higher grades than their counterparts in the other three profiles. While using the same variables in elementary schools, Corpus and Wormington (2014) identified three profiles of motivation: primarily intrinsic, primarily extrinsic and high quantity (characterised with high levels of both motivations). Students in the primarily intrinsic cluster outperformed their peers in the other two clusters.

In a study of motivation for Science learning in 937 pre-High School students, Chittum and Jones (2017) identified five profiles: (i) low motivation; (ii) low usefulness and interest but high success; (iii)somewhat high motivation; (iv) somewhat high motivation and high success; and (v) high motivation.These profiles differed significantly in Science scores, interest and perceived usefulness of Science.Specifically, students in the high motivation profile indicated high science scores, interest and Science usefulness.

The aforementioned studies were conducted in developed countries. Low-and-middle income countries such has Uganda have secondary school Physics curricula and Physics classroom settings (characterised by inadequate laboratory space, limited teaching materials and high teacher–student ratio) that are different from those in developed countries. These factors among others have been found to affect students' motivation (Potvin & Hasni, 2014). Thus, it may not be appropriate to generalise findings from person-centred motivation studies in developed countries to low-and-middle income countries. Moreover, most studies have explored motivation patterns in Science or Mathematics and not in Physics.

5.2.2 Attitudes, Individual interest, and Gender as predictors of Profile Membership

Previous studies have noted associations between gender, attitudes, interest and motivation for Science learning. Some studies (e.g., Potvin & Hasni, 2014) have revealed that students' attitudes predict their motivation for Science learning. Other studies indicate that interest predicts motivation for learning Physics (Kwarikunda et al., 2020). Contradictory results in prediction studies of gender on motivation exist. Whereas some studies (e.g., Glynn et al., 2011; Green et al., 2007; Sjøberg & Schreiner, 2010) indicate gender as a predictor of students' motivation for Science learning, others (e.g., Kwarikunda et al., 2020) report that gender has no influence on students' motivation for Science learning. However, there is a paucity of research on the prediction pathway of attitudes towards Physics and individual interest in Physics learning motivation profile membership, particularly in developing nations.

5.3 Methods

5.3.1 Participants

Participants were 923 (56%) female and 411 (44%) male Grade 9 students from eight randomly selected secondary schools in Masaka District (Central Uganda). Five female and four male students (from the initial 934 students) did not sign the consent form and were thus eliminated from data analysis. The majority of participants were aged between 14 and 15 years (mean = 14, SD = 1.51), and resided at home (n = 475, 51%).

5.3.2 Procedures

Ethical approval was gained from the relevant University Research Ethics Committee. With per-mission from the school administrators, students were contacted and briefed about the aim and purpose of the study. Students provided written consent. The questionnaires were then administered to students during a Physics class in the presence of at least one of the researchers and a research assistant. Participants used approximately 45 minutes to complete the questionnaire. Participation was voluntary, and anonymity of the students and schools was guaranteed.

5.3.3 Measures

Motivation

Students' motivation for Physics learning was assessed using a 24-item Physics version of modified Science Motivation Questionnaire II (MPMQII; Kwarikunda et al., 2020; original version by Glynn et al. (2011)). Words such as 'Science' and 'grade A' were replaced with 'Physics' and 'between 75% and 100%' respectively, to fit into the context of the study. The instrument has five subscales: intrinsic motivation, grade motivation, career motivation, self-efficacy and self-determination. All of the items were answered on a five-point Like rt scale ranging from 1 (never) to 5 (always). Internal consistencies as indexed by Cronbach's α were 0.66 – 0.78 and considered satisfactory (see Table 5.1). Confirmatory factor analysis (CFA) indicated that a five-factor model solution fitted with the data.

Attitudes towards Physics learning

Students' attitudes towards Physics learning were assessed using a 14-item subscale (Physics learning attitudes) of the Physics Attitude Scale (PAS; Kaur & Zhao, 2017). Items were scored on a five-point Like rt scale with anchors ranging from strongly agree (5) to strongly disagree (1). An example item includes 'I wait eagerly for the Physics period'. The internal consistency of the subscale was good (α = 0.86).

Individual Interest

Students' individual interest in Physics learning was assessed using the Individual Interest Questionnaire (IIQ; Rotgans, 2015). The scale consists of seven items e.g. 'I am very interested in Physics',and 'Outside of school, I read a lot about Physics' that were rated on a five-point Likert scale,ranging from 1 (not true at all) to 5 (very true for me). The reliability coefficient of the IIQ was satisfactory (α = 0.74).

Cognitive learning Strategies Use

Different aspects of cognitive learning strategies (i.e., rehearsal, elaboration, critical thinking, organisation) and metacognition were assessed using the cognitive learning strategies section of the Motivated Strategies Learning Questionnaire (Pintrich et al., 1991). All items were answered on a seven-point Likert scale ranging from 7 (very true of me) to 1 (not at all true for me). An example of the items that assessed rehearsal use is 'When studying for Physics, I read my class notes over and over again'. Reliability coefficients were in the acceptable range (see Table 1)

5.3.4 Data Analysis

Preliminary Analyses

To ascertain their suitability for use in the main analyses, data were first screened for missing values,outlier, normality, sampling adequacy and sphericity. Less than 0.5% missing values were noted and handled by the full-information-maximum-likelihood method, since this method is more efficient as compared with other methods (Wang & Wang, 2019). The Shapiro–Wilk test, as a test for normality, resulted in a non-significant value ($p = 0.78$), which indicates that the distribution of our data was normal. We conducted the Kaiser–Meyer–Olkin Measure of Sampling Adequacy, and our data passed this test (KMO = 0.93). Also, Bartlett's test of sphericity indicated that the correlation matrix of items was of adequate quality (χ^2 = 2571.65, d.f. = 276, $p < 0.05$). CFA was then conducted to ascertain the fit of the factors with our data. We followed Hu and Bentler's (1999) model fit criteria: comparative fit index (CFI) and Tucker–Lewis index (TLI) $\geq$ 0.90, standardised root mean square residual (SRMR) $\leq$ 0.08 and root mean square error of approximation (RMSEA) $\leq$ 0.06. Correlations were also done to assess the relatedness of the study variables (see Table 5.1).

Latent Profile Analysis

After data screening, we conducted an LPA using Mplus 8 (Muthén & Muthen, 2017). To detect and choose the correct model and number of profiles, we used six model selection criteria. These were Akaike's information criterion (AIC; Akaike, 1974), Bayesian information criterion (BIC; Schwarz, 1978), sample-size adjusted BIC (ABIC; Sclove, 1987), the Lo-Mendell-Rubin likelihood ratio test(LMR), parametric bootstrapped likelihood ratio test (BLRT) and entropy, as suggested by previous research (e.g., Morin & Wang, 2016). A model that produces lower values of AIC, BIC and ABIC has better fit (Muthén & Muthen, 2017). The LMR and BLRT compare the estimated model ***k*** with a model that has one profile less than the estimated model ***k-1***. Probability values $>$ 0.05 indicate that the ***k-1*** class model provides a significantly better fit to the data than the ***k*** class model (Wang and Wang, 2012). Entropy assesses the adequacy of profile membership classification. An entropy value greater than 0.8 indicates that the latent profiles are highly discriminating (Wang & Wang, 2012). We further examined closely the posterior classification probabilities and profile size distribution (as suggested by Wang & Wang, 2012)). A model with posterior classification probability values $>$ 0.9 for all profiles indicates adequate membership allocation. A profile with size of $<$ 5% is problematic,and thus it is recommended to reject a model with such a profile size.

Differences in Students' Cognitive Learning Strategies and Predictors of Profile Membership

We used the three-step approach as suggested by Hickendorff et al. (2018) , whilst in the one-step approach, external variables are incorporated as covariates in the initial model estimation stage. In the three-step approach, the investigation of association of external variables with the assigned profiles is done after model identification. The latter approach was used since the covariates do not interfere with latent profile classification (Wang & Wang, 2012). After identifying the final model, we explored how (i) the profiles differed on use of cognitive learning strategies and (ii) profile membership was predicted by other factors (gender, individual interest and attitudes) using the AUXILLIARY (e) and (r) statements, respectively, in the LPA rerun (Wang & Wang, 2012). The inclusion of the covariates at this stage in the model helps to limit Type 1 errors Vermunt, 2010), which are common problematic issues when using the one-step LPA approach. Chi square (χ^2) and p-values of the Equity tests were noted to describe the differences in cognitive learning strategy as a function of profile type. Probability values from the test of categorical latent variable multinomial logistic regression were noted to describe the predictions.

5.4 Results

Preliminary Results

For the CFA, the MPMQII (CFI = 0.94, TLI = 0.93, RMSEA = 0.062, SRMR = 0.041), the IIQ (CFI = 0.97, TLI = 0.95, RMSEA = 0.088, SRMR = 0.036) and PAS (CFI = 0.93, TLI = 0.92, RMSEA = 0.072, SRMR = 0.38) scales revealed acceptable fit indices, thus supporting the factor validity of the measures we used with our study population. Correlations of the study variables were all positive and significant ($p < 0.01$) ranging from 0.29 to 0.74 as indicated in Table 5.1.

Table 5.1

Descriptive Statistics and Correlations between the Study Variables of the Overall Sample.

	M (SD)	1	2	3	4	5	6	7	8	9	10	11	12	α
Motivation														
1. IM	2.54 (1.02)	-	0.61	0.61	0.55	0.53	0.56	0.56	0.47	0.42	0.44	0.46	0.47	**0.72**
2. SE	2.96 (1.04)		-	0.56	0.62	0.65	0.41	0.44	0.34	0.36	0.34	0.34	0.39	**0.78**
3. SD	2.82 (0.93)			-	0.50	0.53	0.50	0.45	0.43	0.42	0.36	0.38	0.43	**0.67**
4. CM	3.01 (1.03)				-	0.57	0.42	0.47	0.36	0.35	0.32	0.34	0.38	**0.75**
5. GM	3.26 (0.92)					-	0.32	0.41	0.26	0.30	0.29	0.31	0.36	**0.66**
Prediction variables														
6. II	2.72 (1.03)						-	0.54	0.45	0.44	0.45	0.43	0.41	**0.78**
7. AT	3.69 (0.47)							-	0.42	0.39	0.39	0.43	0.45	**0.72**
Cognitive strategies														
8. RE	5.16 (1.32)								-	0.63	0.64	0.63	0.67	**0.82**
9. OG	5.23 (1.02)									-	0.63	0.62	0.65	**0.84**
10. EL	5.26 (1.14)										-	0.65	0.76	**0.87**
11. CT	4.25 (1.17)											-	0.65	**0.80**
12. MC	5.25 (1.03)												-	**0.89**

Note. IM, intrinsic motivation; SE, self-efficacy; SD, self-determination; CM, career motivation; II, individual interest; AT, attitudes towards physics learning; RE, rehearsal; OG, organization; EL, elaboration; CT critical thinking; MC, metacognition. All correlation values were significant when $p < 0.01$.

5.4.1 Latent Profile Analysis of students' Motivation for physics learning

As presented in Table 5.2, the AIC and ABIC decreased as the number of the profiles increased. The BRLT improved from the four-profile model. The six-profile model was considered the best since: (i) the BLRT$p <$was significant and the profiles were easily distinguished; (ii) the BIC was lowest; (iii) its entropy was higher than that of the five-profile model; and (iv) profile compositions were better for all classes unlike in the five-profile model (Table 5.2).

Table 5.2

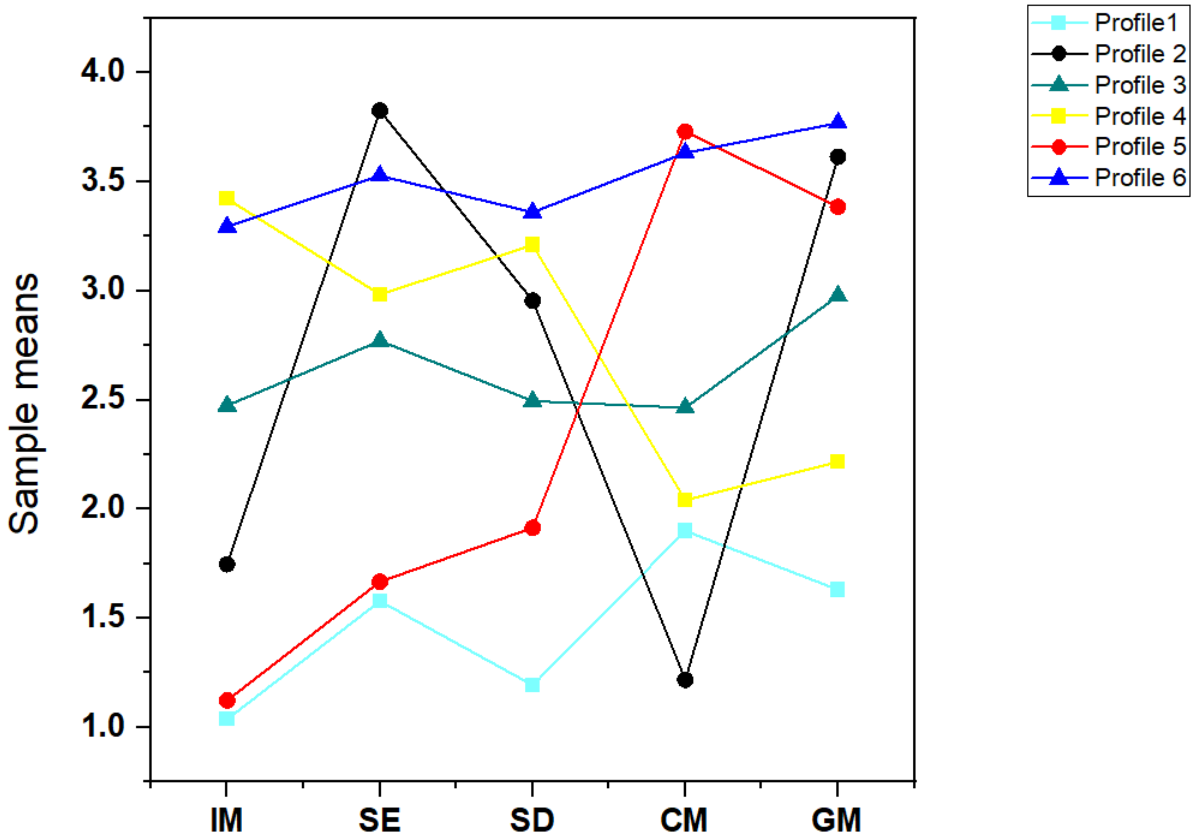
Model Fit Indices for the Models with number of Latent Profiles ranging from 1 to 7

	Model						
Fit statistics	1-profile	2-profile	3-profile	4-profile	5-profile	6-profile	7-profile
FP	10	16	22	28	34	40	46
Log L	-2453.17	-1978.65	-1826.78	-1789.13	-1736.26	-1678.34	-1601.52
AIC	4356.16	3978.45	3876.98	3723.45	3642.86	3597.35	3587.45
BIC	4872.45	4089.26	3912.34	3872.54	3738.12	3652.32	3765.75
ABIC	4678.24	4357.24	4203.24	3972.98	3708.34	3646.23	3534.98
Entropy	-	0.861	0.832	0.801	0.843	0.91	0.752
LMR LR	-	< 0.001	0.009	0.301	0.19	0.23	0.33
aLMR	-	< 0.001	0.012	0.25	0.21	0.24	0.34
BLRT	-	< 0.001	<0.001	0.018	0.04	0.04	0.19
Profiles with <5% composition	-	-	-	-	1	-	1

Note. FP, free parameters; Log L, model loglikelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion, ABIC, sample-size adjusted BIC; LMRLR, Lo-Mendell-and Rubin likelihood ratio test; aLMR, adjusted Lo-Mendell-and Rubin likelihood ratio test; BLRT, bootstrap likelihood ration Test. Bold indices are for the selected model.

Figure 5.1

Graph showing variation of Sample Means scores of the different Profiles for the various Motivation Constructs.



Note. IM,intrinsic motivation; SE, self-efficacy; SD, self-determination; CM, career motivation; GM, grade motivation Class.

5.4.2 Descriptive Statistics of the Six Motivation Profiles.

Two major groups of profiles were identified: the quantity and quality groups of motivation profiles (Figure 5.1). The quantity group comprised profiles 1, 5 and 6 with varying levels (amounts) of motivation. Profile 1 (n = 101, 10.8%) consisted of students characterised with the 'lowest' levels of motivation and thus was named the low-quantity motivation (LQM) profile. Profile 5 (n = 246, 26.3%)consisted of students with 'moderate' levels of motivation when compared with profiles 1 and 6. This profile was named the moderate-quantity motivation

(MQM) profile. Profile 6 consisted of the largest student population (n = 365, 39.1%) with the 'highest' level of motivation when compared with profiles 1 and 5, thus it was named the high-quantity motivation (HQM) profile.The quality group of profiles comprised three profiles (i.e. profiles 2–4). Profile 2 (n = 60, 6.4%) comprised students with the highest intrinsic motivation mean score. Given that their self-efficacy and self-determination were higher than their goal and career motivation, this profile was named the primarily intrinsically motivated (MPI) profile. Profile 3 (n = 74, 7.9%) comprised of students with the highest self-efficacy and grade motivation but with very low career and intrinsic motivation. This profile was named the grade-introjected (GI) profile. Lastly, profile 4 (n = 88, 9.4%), named the mostly extrinsically motivated (MEM) profile, comprised students with higher scores of grade and career motivation (extrinsic) than intrinsic motivation

5.4.3 Differences in Students' Cognitive Learning Strategy use across the six Motivation Profiles

There were significant differences in students' cognitive strategy use across the six profiles (see Table3). Students in the MPI profile (profile 2) scored highest on four of the five indicators of cognitive learning strategies. Profiles 1 (LQM), 3 (GI) and 4 (MEM) indicate that students in these profiles use less critical thinking (χ^2 = 0.82, $p = 0.36$) and metacognition (χ^2 = 2.10, $p = 0.44$) learning strategies during Physics learning. In contrast, students in Profiles 2 (MPI) and 6 (HQM) use organisation (χ^2 = 3.45, $p = 0.23$), critical thinking (χ^2 = 0.94, $p = 0.14$) and metacognition (χ^2 = 3. 84, $p = 0.43$) learning strategies more during Physics learning.

Table 5.3

Equality Tests of Means across Profiles using the 3-step Procedure

Cognitive learning strategy	Profile LQM (1)	MPI (2)	GI (3)	MEM (4)	MQM (5)	HQM (6)	χ^2	Differences between profiles
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)		
Rehearsal	4.19 (0.19)	5.21 (0.18)	6.03 (0.17)	4.98 (0.94)	4.70 (0.13)	5.56 (0.09)	**50.73***	1<5<4<2<6<3
Organisation	4.20 (0.20)	5.76 (0.19)	4.24 (0.76)	5.09 (0.98)	4.89 (0.13)	5.69 (0.96)	**55.89***	1=3<5<4<6=2
Elaboration	4.39 (0.19)	6.54 (0.09)	4.23 (0.98)	4.07 (0.96)	4.78 (0.12)	5.83 (0.78)	**82.23***	1=4<3<5<6<2
Critical thinking	4.03 (0.17)	5.42 (0.18)	4.07 (0.98)	4.25 (0.96)	4.14 (0.12)	5.28 (0.96)	**65.26***	1=3=4=5<6=2
Meta-cognition	4.39 (0.15)	6.35 (0.16)	4.47 (0.09)	4.53 (0.17)	4.83 (0.09)	5.90 (0.06)	**94.46***	1=3=4<5<6=2

*significant, $p < 0.05$

***Note*.** MPI, primarily intrinsically motivated ; LQM, low-quantity motivation; GI, grade-introjected; MEM, mostly extrinsically motivated; MQM, moderate-quantity motivation; HQM, high-quantity motivation.

5.4.4 Predictors of Profile Membership

The results of the categorical latent variable multinomial logistic regression (see Table 4) indicated that, unlike gender, individual interest and students' attitudes to Physics learning significantly predicted profile membership. Students with low individual interest are more likely to be placed in the LQM profile than in the MPI profile (β = 0.37, SE = 0.29, $p = 0.29$) or the HQM profile (β = 0.36, SE = 0.31, $p = 0.28$). Students with highly positive attitudes towards Physics learning are more likely to be placed in the GI and HQM profiles than in the LQM (β = 0.012, SE = 0.39, $p = 0.18$) or MEM (β = 0.28, SE = 0.31, $p = 0.38$) profile.

Table 5.4

Statistics from a Categorical Latent Variable Multinomial Logistic Regression using MPI as the Reference Profile

Reference profile	Profile	Predictor		
		Gender	Individual interest	Attitudes
MPI	LQM	-0.018 (0.36)	**-0.370 (0.29)***	**-0.168 (0.39)***
	GI	0.420 (0.33)	0.046 (0.89)	**0.350 (0.34)***
	MEM	0.012 (0.25)	**0.260 (0.31)***	0.110 (0.31)
	MQM	0.280 (0.21)	0.024 (0.09)	**-0.012 (0.06)***
	HQM	-0.270 (0.12)	**-0.360 (0.31)***	**0.360 (0.24)***

β**(S.E)*** significant when $p < 0.05$

***Note*.** MPI, primarily intrinsically motivated; LQM, low-quantity motivation; GI, grade-introjected; MEM, mostly extrinsically motivated; MQM, moderate-quantity motivation; HQM, high-quantity motivation.

5.5 Discussion

Following recommendations by Muthén and Muthen (2017) and Wang and Wang (2012) , we used a person-centred approach to reveal six distinct profiles of secondary school students characterised by differing quantity and quality of motivation during Physics learning. In comparison with other studies,our findings were similar to those of Lazarides et al. (2016) in which they identified three quantity profiles (low motivation, moderate motivation and high motivation). However, their utility profile had no similarity with any of our qualitative profiles. In another study by Hayenga and Corpus (2010), although no moderate-quantity motivational profile was identified, they also identified the low- and high-quantity motivation profiles. Similarly, Corpus and Wormington (2014) identified three qualitative profiles of students with differing ratios of intrinsic to extrinsic motivation. Unlike in both studies (in Germany and USA), we identified a group of students characterised by the highest self-efficacy and grade motivation scores but with lower intrinsic motivation and lowest career motivation scores. These students have high believe that they can perform well in Physics, regardless of their low intrinsic drive and personal desire to pursue a career in Physics. Perhaps, the presence of this profile in our sample is due to the structure of secondary schools in Uganda, in which students experience increasing control and affirmation from teachers and parents that they can actually obtain good grades (Ekatushabe et al., 2021) regardless of their intrinsic motivation and value for pursuing the subject.Corpus and Wormington (2014) suggests that students whose ability beliefs are influenced by their peers and parents tend to largely favour their extrinsic concerns over their intrinsic motives and interests, which could undermine the development these students' intrinsic motivation.

In terms of profile prevalence, similarly to Lazarides et al. (2016) study, the high-quantity motivation profile was the most prevalent profile in our sample, a pattern of motivation that perhaps characterises high school students owing to the competitive and outcome-oriented stance common at this level of schooling (Corpus & Wormington, 2014). Given that intrinsic motivation has been found tobe positively related to students' levels of performance

(Vansteenkiste et al., 2009), their enduring long-term interest in learning (Kwarikunda et al., 2020) and engagement in classroom activities (Green et al., 2007), we expected more students in the primarily intrinsic motivation profile.However, as early as Grade 9, this profile registered the lowest membership. Wormington et al., 2012 suggest that exhibiting high or similar levels of intrinsic and extrinsic motivation is more adaptive during Science learning. Nevertheless, the results of our study provide further supportive evidence that indeed contextual, subject-specific and individual differences exist in secondary school students' motivation.

As hypothesised, students in the distinct profiles differed significantly in their cognitive learning strategy usage. Whereas LQM, GI and MQM students used more surface learning strategies, their counterparts with higher quality and quantity motivation used adaptive learning strategies more frequently. Highly motivated learners are more likely to have high academic persistence and cognitive engagement, exhibit a high sense of control of their learning beliefs and mastery goals, and tend to use adaptive cognitive learning strategies that result in deep learning to reach their learning goals compared with those with low motivation (Potvin & Hasni, 2014; Schiefele, 1999).

Concerning the prediction of latent profile membership, students' attitudes towards Physics and individual interest predicted profile membership, unlike gender. We agree with Zeyer (2010), who argued that attitudes, interest and cognitive styles might be much better predictors for explaining motivation to study Physics than gender. Studies (e.g., Kwarikunda et al., 2020; Sjøberg & Schreiner, 2010) have revealed no statistically significant gender differences in students' motivation for Physics and Science learning in developing countries. Hence Physics teachers should help students increase their motivation for learning Physics irrespective of students' gender.

5.6 Educational Implications

We have demonstrated using LPA that students differ in their quality and quantity of motivation for learning Physics. Teachers should be aware that students vary in their motivation for Physics learning and that these variations are associated with their cognitive learning strategy usage, individual interest and attitudes towards Physics learning. Thus teachers need to adopt their instructional behaviours to suit the needs of the different profiles of the students if effective Physics learning is to occur.

Rather than the MPI profile, the HQM profile was much more prevalent, perhaps because teachers emphasise overall motivation for Physics learning. Although HQM students report strong performance and (Corpus & Wormington, 2014; Wormington et al., 2012) found that good-quality motivated students(high intrinsic motivation relative to external regulation) obtain stronger academic performance and are lifelong learners. Much as it is important to motivate students extrinsically, teachers should note that intrinsic motivation is more advantageous to develop life learning (Hayenga & Corpus, 2010; Kwarikunda et al., 2020). To foster the development of intrinsic motivation in LQM, EM and GI profiles, firstly, teachers should provide an autonomous Physics classroom climate in which students are provided with options and opportunities to make their own decisions, as well as feeling that they have control over their environment and learning. Secondly, Physics teachers should give students instructions in self-reliant behaviours that promote self-regulation (Kwarikunda et al., 2020; Muwonge et al., 2020).

To improve students' motivation and their cognitive learning strategies, students' attitudes and individual interest should be boosted (given their predictive role on motivation). Ong and Ruthven (2009) suggested the use of inquiry-based learning with emphasis on 'hands-on' learning and laboratory work. This not only encourages student-driven discoveries and visualisations-correcting the abstract notion about the subject but also develops their metacognitive skills. 'Hands-on' learning arouses curiosity, enthusiasm and enjoyment in Physics learning (Potvin & Hasni, 2014).Rather than competitive and individualistic tasks, Shachar and Fischer (2004) advise teachers to shift to collaborative tasks since task sharing improves students' confidence, interest and attitudes. During such collaborative tasks, much attention, clear simplified instructions and constant feedback should be given to sustain students' motivation and engagement. Working in groups develops students' beliefs about their capabilities as a group, consequently improving on their motivation for learning Physics. Rather than letting students struggle with surface learning skills, Zeyer (2010) recommends that students be taught (and trained in) the various cognitive learning skills (with much focus on deep-level learning strategies) so that they can put into practice such skills during Physics learning.

5.7 Limitations

First, questionnaires were used to collect data. Such self-report measures are prone to bias and social desirability (Rotgans, 2015). To triangulate quantitative findings, future studies can employ mixed methods approaches. Secondly, some subscales had low reliabilities (below the conventional cut-off of 0.70). However, we retained these subscales following the recommendation by Vermunt (2010) . Thirdly, to draw conclusions about the causal directions of the examined effects, further longitudinal studies can be designed to examine the direction of these effects as well as the trajectories ofthe profile membership.

5.8 Conclusion

This study confirms that individual differences with regard to motivation for Physics learning exist. Six profiles of students' motivation for Physics learning were identified. More so, the profiles differed significantly with regard to cognitive learning strategy usage. Students in the high quantity and primarily intrinsically motivated profiles used strategies that enhance deep learning as compared with their counterparts. Unlike gender, individual interest and attitudes towards Physics learning predicted profile membership. Students with low attitudes towards Physics learning and low individual interest were more likely to be placed in low quantity and mostly extrinsically motivated profiles. To improve the quality of students' motivation during Physics learning, teachers should emphasise autonomous,democratic and self-paced pedagogical settings.

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References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control*, *19*(6), 716–723.

Ardura, D., & Pérez-Bitrián, A. (2019). Motivational pathways towards academic achievement in physics & chemistry: A comparison between students who opt out and those who persist. *Chemistry education research and practice*, *20*(3), 618–632.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*(23-28).

Chittum, J. R., & Jones, B. D. (2017). Identifying pre–high school students' science class motivation profiles to increase their science identification and persistence. *Journal of Educational Psychology*, *109*(8), 1163.

Corpus, J. H., & Wormington, S. V. (2014). Profiles of intrinsic and extrinsic motivations in elementary school: A longitudinal analysis. *The Journal of Experimental Education*, *82*(4), 480–501.

Ekatushabe, M., Kwarikunda, D., Muwonge, C. M., Ssenyonga, J., & Schiefele, U. (2021). Relations between perceived teacher's autonomy support, cognitive appraisals and boredom in physics learning among lower secondary school students. *International Journal of STEM Education*, *8*(1), 1–15.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire ii: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159–1176.

Green, J., Martin, A. J., & Marsh, H. W. (2007). Motivation and engagement in english, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences*, *17*, 269–279.

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion*, *34*(4), 371–383.

Hickendorff, M., Edelsbrunner, P. A., McMullen, J., Schneider, M., & Trezise, K. (2018). Informative tools for characterizing individual differences in learning: Latent class, latent profile, and latent transition analysis. *Learning and Individual Differences*, *66*, 4–15.

Kaur, D., & Zhao, Y. (2017). Development of physics attitude scale (pas): An instrument to measure students' attitudes toward physics. *The Asia-Pacific Education Researcher*, *26*(5), 291–304.

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, *54*(5), 586–614.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in uganda. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 435–446.

Lazarides, R., Rubach, C., & Ittel, A. (2016). Motivational profiles in mathematics: What role do gender, age and parents' valuing of mathematics play? *International Journal of Gender, Science and Technology*, *8*(1), 124–143.

Meece, M. G., Judith L.and Jones. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching*, *33*(393-406).

Morin, A. J., & Wang, J. C. (2016). A gentle introduction to mixture modeling using physical fitness performance data. John Wiley & Sons.

Muthén, L. K., & Muthen, B. (2017). *Mplus user's guide: Statistical analysis with latent variables, user's guide*. Muthén & Muthén.

Muwonge, C. M., Ssenyonga, J., Kibedi, H., & Schiefele, U. (2020). Use of self-regulated learning strategies among teacher education students: A latent profile analysis. *Social Sciences & Humanities Open*, *2*(1), 100037.

Ong, E.-T., & Ruthven, K. (2009). The effectiveness of smart schooling on students' attitudes towards science. *Eurasia Journal of Mathematics, Science and Technology Education*, *5*(1), 35–45.

Pintrich, P. R., et al. (1991). A manual for the use of the motivated strategies for learning questionnaire (mslq).

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: A systematic review of 12 years of educational research. *Studies in science education*, *50*(1), 85–129.

Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In *Intrinsic and extrinsic motivation* (pp. 373–404). Elsevier.

Rotgans, J. I. (2015). Validation study of a general subject-matter interest measure: The individual interest questionnaire (iiq). *Health Professions Education*, *1*(1), 67–75.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299–323.

Schiefele, U. (1999). Interest and learning from text. *Scientific studies of reading*, *3*(3), 257–279.

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education*, *38*(3), 434–449.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics*, 461–464.

Sclove, S. L. (1987). Application of model-selection criteria to some problems in multivariate analysis. *Psychometrika*, *52*(3), 333–343.

Shachar, H., & Fischer, S. (2004). Cooperative learning and the achievement of motivation and perceptions of students in 11th grade chemistry classes. *Learning and instruction*, *14*(1), 69–87.

Sjøberg, S., & Schreiner, C. (2010). *The rose project. an overview and key findings. rose publications.*

UNEB. (2017). Statement of release of 2017 uce examination results. https://uneb.ac.ug/

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of educational psychology*, *101*(3), 671.

Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political analysis*, *18*(4), 450–469.

Wang, J., & Wang, X. (2012). *Structural equation modeling with mplus: Methods and applications*. Wiley.

Wang, J., & Wang, X. (2019). *Structural equation modeling: Applications using mplus*. John Wiley & Sons.

Watt, H. M., Bucich, M., & Dacosta, L. (2019). Adolescents' motivational profiles in mathematics and science: Associations with achievement striving, career aspirations and psychological wellbeing. *Frontiers in Psychology*, *10*, 990.

Wormington, S. V., Corpus, J. H., & Anderson, K. G. (2012). A person-centered investigation of academic motivation and its correlates in high school. *Learning and Individual Differences*, *22*(4), 429–438.

Zeyer, A. (2010). Motivation to learn science and cognitive style. *Eurasia Journal of Mathematics, Science and Technology Education*, *6*(2), 121–128.

CHAPTER 6

ARTICLE 3

Profiles of learners based on their Cognitive and Metacognitive learning strategy use: Occurrence and relations with Gender, Intrinsic Motivation, and perceived Autonomy Support.

Kwarikunda, D., Schiefele, U., Muwonge, C. M. , & Ssenyonga, J.(2022) Profiles of learners based on their cognitive and meta cognitive learning strategy use: occurrence and relations with gender, intrinsic motivation, and perceived autonomy support. *Humanities and Social Sciences Communication, 9*, article 337.

Abstract

For lifelong learning, an effective learning strategy repertoire is very important during acquisition of knowledge in lower secondary school- an educational level characterized with transition into more autonomous learning environments with increased complex academic demands. Using latent profile analysis, we explored the occurrence of different secondary school learner profiles depending on their various combinations of cognitive and metacognitive learning strategy use, as well as their differences in perceived autonomy support, intrinsic motivation, and gender. Data were collected from 576 9^{th} grade students in Uganda using self-report questionnaires. Four learner profiles were identified: competent strategy user, struggling user, surface-level learner, and deep-level learner profiles. Gender differences were noted in students' use of elaboration and organization strategies to learn Physics, in favour of girls. In terms of profile memberships, significant differences in gender, intrinsic motivation and perceived autonomy support were also noted. Girls were 2.4 - 2.7 times more likely than boys to be members of the competent strategy user and surface-level learner profiles. Additionally, higher levels of intrinsic motivation predicted an increased likelihood membership into the deep-level learner profile, whilst higher levels of perceived teacher autonomy predicted an increased likelihood membership into the competent strategy user profile as compared to other profiles. Further, implications of the findings were discussed.

Key words: Learner profiles, cognitive learning strategies, lower secondary school, Physics learning.

6.1 Introduction

One of the main objectives of Science education is to produce students who are independent, autonomous, think like scientists, and are efficient lifelong learners (Bin, 2008; Tanner, 2002). Despite the vast amount of resources many countries have devoted to STEM education (Keller et al., 2017), there has been an outcry over the poor achievement of students in Science subjects (Christidou, 2011; Eccles & Wigfield, 2002; Keller et al., 2017; Potvin & Hasni, 2014) especially Physics (Kwarikunda et al., 2020) at secondary school level in both developed and developing countries. Uganda has had its own share of this experience (see Kwarikunda et al., 2020). Additionally, gender differences in Physics achievement have been reported in favour of boys (Organisation for Economic Cooperation and Development; OECD, 2010), consequently affecting the number of girls that opt for Physics-oriented careers. Whereas many countries strive to narrow the gender gap in Physics careers-careers that have been labelled masculine, minimum progress is registered (OECD, 2010) especially in developing countries.

Evidence indicates that students' performance in Science is influenced by a number of affective factors such as their motivation (e.g., OECD, 2010; Ratelle et al., 2007a), interest, attitudes, and use of learning strategies (Bouckenooghe et al., 2016; Schunk et al., 2008; Sjøberg & Schreiner, 2010) . Highly motivated students are usually interested in classroom activities, are enthusiastic, and engage more in the learning process than their counterparts. Further, autonomous motivation has been reported to be advantageous to achievement (Vansteenkiste et al., 2009) and other learner outcomes. To foster the development of autonomous motivation, some teachers integrate aspects to support the development of autonomy during instruction. However, the perception of these instructions by the learners to feel supported for autonomy development during science learning are important, since perceived teacher autonomy support has direct and indirect effects on learners' motivational beliefs, attitudes, achievement emotions, choice of learning skills (Ekatushabe et al., 2021; Zhao & Qin, 2021), and their achievement. In the present study, we focus on the predictive effects of autonomy support on the membership likelihood of different latent profiles of learners based on their cognitive and metacognitive learning strategy use.

Previous research highlights that learners differ in their ability to use learning strategies (Schunk et al., 2008): autonomously motivated students using more adaptive learning strategies such as critical thinking than their counterparts who adopt maladaptive learning strategies such as rote learning and rehearsal (Manganelli et al., 2019; Rogiers et al., 2019) suggested that lack of a well-adapted cognitive learning strategy repertoire could negatively affect the students' academic progress. Whereas much research has been done in Science in general and Mathematics, little is known about students' repertoire of cognitive learning strategy use during Physics learning especially in lower secondary school, an educational level that is characterized of (i) transition into more independent learning and autonomous classroom situations and (ii) decline in levels of motivation to learn (Barmby et al., 2008). Additionally, for effective gender-based pedagogical innovations to counter the gender gap in Physics achievement and consequently in Physics career choice, it is vital to examine gender differences in cognitive learning strategies in Physics. To this end, we used a person-centered approach to explore the various profiles of students based on their cognitive strategy use during Physics learning. Further, we investigated differences in gender, intrinsic motivation and autonomy support within the various profiles of students' cognitive strategy use.

6.1.1 Theoretical Framework

Since the late 1970's, fostering lifelong learning became an important educational goal in many countries worldwide (Rogiers et al., 2019). With the growing need to train self-reliant, independent, and critically thinking citizens that meet the constantly evolving demands of the job and market world (Muwonge et al., 2020), many countries consequently shifted their pedagogical practices from teacher- centered approaches to learner-centered approaches. Consequently, control of the learning process in the learner-centered classrooms shifted from the teachers to the learners. Thus, in such classrooms, the role of teachers shifts from classroom lecturer who presents information to students to "facilitators" of the learning process, learners solely taking up the responsibility to understand their learning environment and control over "how" and "when" they should learn a given academic task. To do so, learners must set learning goals, select strategies that help them achieve their learning goals, implement these strategies and monitor their own progress towards achieving their learning goals (Schunk et al., 2008). Such learners are said to self-regulated (Pintrich & Zusho, 2002).

The self-regulated learning theory contends that learning is governed by a variety of interactions between the cognitive, metacognitive and motivational components of an individual (Pintrich, 2000; Pintrich & Zusho, 2002; Zimmerman, 2000). Cognition includes different skills learners use to encode, memorise, and recall information (Schraw et al., 2006). Meta cognition involves skills learners use to understand, monitor, and regulate their cognition process (Pintrich, 2000; Zimmerman, 2000). Motivation includes the various beliefs that drive the use and development of cognitive and metacognitive skills during learning (Pintrich, 2000).

6.1.2 Motivation as a component of Self-regulation

Within the self-regulation framework, motivation plays an important role in explaining the value and belief system that students have when it comes to goal setting and choice of the learning strategies to use (Pintrich, 1999; Zimmerman, 2000). Although different models of self-regulation highlight different components of motivation, Pintrich et al. (1993) and colleagues' model encompass self-efficacy, intrinsic motivation and extrinsic motivation. Self-efficacy is important for self-regulated learning because it affects the extent to which learners engage and persist at challenging tasks (Schraw et al., 2006; Zimmerman, 2002). Extrinsic motivation allows learners to participate in a learning activity for the sake of external rewards such as grades. Intrinsic motivation is the drive students feel when they do an academic task because it is inherently interesting and enjoyable (Ryan & Deci, 2000). Intrinsically motivated students pursue learning activities because of personal choice absence of external contingency regardless of the task difficulty and are more likely to engage in effective cognitive learning strategies (Deci & Ryan, 2000; Vansteenkiste et al., 2009).

Of the various ways of regulating academic motivation, intrinsic motivation has been highlighted as most advantageous to academic achievement (Corpus & Wormington, 2014;

Deci & Ryan, 2000; Hayenga & Corpus, 2010; Ryan & Deci, 2000; Schiefele, 1991). However, if intrinsic motivation is to be improved, learners need to be autonomous - a perception of being the source of one's own learning behaviours (Deci & Ryan, 2000; Manganelli et al., 2019). To achieve their own learning goals with psychological freedom and satisfaction, students require autonomy support. Kusurkar and Croiset (2015) define autonomy support as the perception of choice and control over one's learning. Autonomy support can be from teachers, peers, parents, and role models. In our study we focused on perceived teacher autonomy support. Self-regulated students are autonomously motivated, study out of curiosity for inherent enjoyment, satisfaction and personal interest with a sense of psychological freedom and perceived internal locus of causality (Manganelli et al., 2019; Vansteenkiste et al., 2009).

6.1.3 Cognitive and Metacognitive learning strategy use

In the cognitive and metacognitive components of the self-regulation theory, Zimmerman, 2000 stresses that for improved learning, learners have to use a variety of individual tactics and skills. These skills were also identified as learning strategies by Pintrich et al. (1993) and colleagues . Depending on the demands and complexity of the given academic task, learners differ in their self-regulation and thus, use a variety of learning strategies (Duncan & McKeachie, 2005). Learning strategies are a set of skills that students choose and effectively use to acquire knowledge, and accomplish different learning tasks and goals (Pintrich et al., 1993). Learning strategies can be categorized according to their nature (i.e., cognitive, metacognitive, and motivational) and level of depth of information processing and internalisation (Rogiers et al., 2019). Deep-level strategies are aimed at deep understanding and active transformation or application of information while surface- level strategies aim at memorisation and basic comprehension without any information integration (Pintrich & Zusho, 2002; Rogiers et al., 2019; Schiefele, 1991).

Cognitive and metacognitive learning strategies involve basic and complex ways in which knowledge is chosen, retained, and processed in relation to previously acquired knowledge (Pintrich et al., 1993). Such ways include use of rehearsal, elaboration, organisation, planning, and monitoring. Rehearsal involves repeated recitation, writing, and naming of the items such as physics formulae and definitions to be learned. Rehearsal is a basic learning strategy through which information in working memory is activated (Pintrich, 2000). Organization is a more active process during which learners select appropriate information through clustering, outlining, and selecting the main idea in reading passage. However, both learning strategies do not allow construction of connectivity among information with prior knowledge but rather emphasize memorization (Pintrich et al., 1993). Consequently, constant use of rehearsal and organisation promotes surface-level learning (Pintrich & Zusho, 2002; Schiefele, 1991).

On the other hand, for deep learning to occur, learners need to use high-order strategies like elaboration and critical thinking (Schiefele, 1991). By building internal connections between items to be learned, students use elaboration strategies such as generative note-taking, making analogies, and effective note taking to store information into long-term memory (Pintrich et al., 1993). At the same time, elaboration strategies help students integrate new learning with existing knowledge (Pintrich et al., 1991). Critical thinking involves a variety of skills such as the learners' ability to identify the source of information, analyse its credibility, reflect on whether that information is consistent with their previously acquired knowledge, apply previously acquired knowledge to new learning situations, make evaluations with respect to the standards of excellence, draw conclusions based on their critical thinking (Linn, 2000; Pintrich et al., 1993) and elaborate their personal opinion about the topics being studied (Cred & Phillips, 2011).

Meta cognition involves students' knowledge of their cognition and their ability to control their cognition. In the self- regulation framework, learners have the responsibility to set learning goals, plan, monitor and evaluate their learning at various points during the learning process (Zimmerman, 1990). Planning involves the selection of appropriate strategies depending of the task at hand, allocating resources, and setting the learning goal (Pintrich et al., 1993; Schraw et al., 2006). Planning activities help to activate, or prime, relevant aspects of prior knowledge that make organizing and comprehending the material easier (Pintrich et al., 1991). Through monitoring strategies, learners are able to track their attention, make judgements of their motivation levels and effectiveness of the learning strategies. Evaluation usually involves accessing their learning goals and effectiveness of their learning strategies. Through evaluation, learners can continue to use a given set of learning strategies deemed effective and or replace those strategies that they find ineffective for a given learning task. Also, through evaluation, learners self-test their learning achievement.

Given that self-regulation is context dependent (Zimmerman, 2000), the way students engage with learning is rarely restricted to use of one single cognitive learning strategy (Bouckenooghe et al., 2016). Pintrich (2000) also affirmed that no strategy is dominant or works equally for all individual learners for a given task. This implies that while some cognitive and metacognitive learning strategies are useful for some students, the same or similar learning strategies may not be equally useful to other students (Dowson & McInerney, 1998). For example, Japanese students have been reported to use mostly memorization, summarization, and rehearsal while learning less enjoyable and abstract academic tasks (Purdie et al., 1996). Elsewhere, in Turkey, 7^{th} grade Science students reported use of meta cognition, rehearsal, and elaboration (Akyol et al., 2010). Additionally, studies have indicated existence of positive relationships between the nature and level of deep of the learning strategies used with achievement. For example, in Japan rehearsal (memorization) was highly associated with achievement (Purdie et al., 1996). In line with Pintrich et al. (1993) , metacognition predicted Turkish students' achievement in Science (see Akyol et al., 2010).

From literature, it is clear that cognitive strategy use varies according to culture, subject and grade level. Whereas secondary education is generally a challenging educational level, the first two years are characterized with transition into more complex and autonomous academic tasks and learning environments. Also, the first two years of secondary school are crucial years in which students develop an effective learning strategy repertoire (Rogiers et al., 2019) if properly guided and supported during instruction. Additionally, during this time, students in Uganda are introduced to new subjects such as Physics, a subject that most lower secondary school Ugandan students have connoted as less interesting, complex and abstract (Kwarikunda et al., 2020). This connotation could affect the students' cognitive learning strategy use.

However, little is known about the cognitive and metacognitive learning strategy usage during Physics learning among lower secondary school students' especially in developing countries.

6.1.4 A Person-oriented approach to Learning Strategies use

Researchers have used theory-driven variable-centered methods to generate much information on effects and associations between several variables such as academic motivation, cognitive strategy use among others in the self- determination framework. However, variable-centered approaches have largely ignored the complex interaction of these variables at the level of the individual (Wang & Wang, 2012). To complement variable-centered studies, researchers have been advised to use data-driven approaches such as person-centered analyses. In person-centered approaches, the underlying latent groups that would have been otherwise been left masked in variable-centered approaches are revealed within the heterogeneous sample (B. Muthén & Muthén, 2000). These groups (profiles) represent people clustered together with similar levels on several variables. Unmasking such profiles is necessary for designing educational interventions that target a specific group's needs.

Since students tend to develop a flexible repertoire of different combinations of cognitive learning strategies during different learning contexts (Rogiers et al., 2019), several studies have explored the various combinations of students' strategy use using a person-centered approach; this helps to unveil the number and characteristics of learner profiles. In elementary school learners, Merchie et al. (2014) and colleagues, identified 4 profiles of learners; memorisers, mental learners, information organisers and integrated strategy users. Most students were categorized as integrated strategy users. Later, Karlen (2016) also identified four profiles of upper secondary students in regard to their reported motivation and cognitive strategy use. It was observed that highly self-regulated students reported highest grades in German.

Among university students, Zheng et al. (2020) identified four profiles of self-regulated learners. The profiles were identified as competent learners, reflective-oriented learners, minimally regulated learners, and cognitive-oriented learners. Although competent learners reported highest scores on motivational process, cognitive strategy use, and behavioural regulation, reflective-oriented learners demonstrated the best academic performance. Similar number of profiles was also previously identified by Ning and Downing (2015) accepted that unlike Zheng et al. (2020) , their competent profile was associated with the highest academic achievement.

Also, whilst using the motivated strategies l for learning questionnaire to examine individual differences in 238 junior college students' motivation and learning strategy use, Liu et al. (2014) uncovered four groups of students. The students in the two adaptive clusters showed better academic achievement. Alternatively, whilst using a sample of Ugandan teacher trainees in six universities, Muwonge et al. (2020) identified three quantitative profiles of science teacher trainees in regard to their learning strategy use. Most first year teacher trainees were categorized as either low or average strategy users. High strategy users reported highest levels of extrinsic goal orientation and test anxiety. Elsewhere, Heikkilä et al., 2012 also identified three profiles of learners based on their learning strategy use. They identified their profiles as non-regulating students, non-reflective students, and self-directed students. The self-directed students reported deeper understanding of concepts and higher critical thinking. Additionally, while using 1326 biology students, Hong et al. (2020) and colleagues, identified three profiles of students according to their metacognitive self- regulated learning usage. They identified their profiles as infrequent metacognitive processing profile, planning and self-evaluation profile, and monitoring via self-assessment target profile.

It should be noted that most of the above studies have been conducted in developed countries whose curricula, academic demands, Physics teacher training programs and classroom settings are different from those of the present study. Additionally, these studies have been done in different subject contexts (e.g., German, STEM, learning in general, and text learning) and education levels. Furthermore, different sets of variables (in addition to cognitive learning strategies) have been used in most studies. Nevertheless, reviewing these studies provides insightful information and comparisons of the person-centered analyses within the self-regulation framework.

6.1.5 Gender differences in Cognitive Learning Strategies use

Prior research has suggested that there are stable gender differences in learning strategy use (Meece & Jones, 1996; Rogiers et al., 2019; Wolters & Pintrich, 1998). Several studies have indicated reasonable gender differences. For instance, it has been revealed that girls show higher levels of cognitive strategy use (Wolters & Pintrich, 1998), are more knowledgeable about the various effective strategies (OECD, 2010), and tend to utilize more learning strategies (Rogiers et al., 2019) than boys. Additionally, some studies have reported that girls prefer to use memorization strategies (e.g., rehearsal) whilst boys prefer to use elaboration strategies (Meece & Jones, 1996; OECD, 2010). On the contrary, in other studies (e.g., Niemivirta, 1997) boys were found to use more memorization strategies than girls. Specifically, Niemivirta (1997) concluded that boys are rote learners since they outperformed girls when using rote learning strategies.

Studies in Mathematics classes indicate that unlike girls, boys are more likely to develop autonomous learning strategies and assume control of their learning (Meece & Jones, 1996). In other studies, Akyol et al. (2010) recorded no significant gender differences in cognitive strategy use during Science learning among 7^{th} grade students in Turkey. Similarly, in 5^{th} and 6^{th} grade Mathematics and Greek language students, Metallidou and Vlachou (2007) reported no significant gender differences in cognitive strategy use. Finally, Bidjerano (2005) reported significant gender differences in only the use of critical thinking in favour of boys.

Due to the various contradictions in reports of gender differences in learning strategy use, it is possible that these differences reflect cultural contexts and nature of the academic tasks (Duncan & McKeachie, 2005). Also, it is unclear of the gender differences in cognitive strategy use among 9^{th} grade students during Physics learning especially in developing countries. Thus, there is a need for further exploration of gender differences in cognitive strategy use during Physics learning especially in developing countries. Results from such an exploration may also inform teacher instructions.

6.1.6 Present study

Previous research (e.g., Muwonge et al., 2020) has already identified different learner profiles with regard to their learning strategy use at different educational levels. However, little attention has been given to learner profiles especially in the context of Physics learning in secondary school–a critical educational level in which learners are expected to become more independent and autonomous during learning situation, as they develop an effective learning strategy repertoire for lifelong learning (Rogiers et al., 2019). Moreover, depending on the nature of the subject and the learners' previous experiences, learners tend to use different combinations of learning strategies. It is unclear which combinations of cognitive learning strategies students use during Physics learning and how many profiles of these combinations exist in secondary schools especially in developing countries such as Uganda. Thus, to fill this research gap, we sought to identify the distinct learner profiles based on their various combinations of cognitive learning strategy use. We hypothesized that more than two latent profiles of learners based on their cognitive learning strategy usage exist; with one profile containing students who are less self- regulatory metacognitively.

Additionally, the male connotation of Physics instruction (Jurik et al., 2014) and Physics careers in society could affect use of cognitive learning strategies and consequently, result into differences in gender distribution within the profiles. Thus, we also explored the likelihood of membership as a result of gender. We hypothesised that the profile that contained students who reported to use more organisation strategies contained more female than male students.

The extent to which students make use of the cognitive learning strategies depends on their motivation (Schiefele, 1991; Stolk & Harari, 2014). In their study using university students, Vansteenkiste et al. (2009) reported that autonomously motivated students (with high levels of intrinsic than extrinsic motivation) exhibited use of a variety of adaptive learning strategies. However, Wormington et al. (2012) and colleagues found that students with higher levels of both intrinsic and extrinsic motivation used adaptive learning strategies. Despite the fact that various forms of motivation have accounted for differences in academic achievement and learning strategy use (Ekatushabe et al., 2021; Manganelli et al., 2019), it is unclear how intrinsic motivation and perceived autonomy support differ in various groups of learners depending on their cognitive strategy use specifically in lower secondary school. Thus, whilst using a person-centered approach, we sought to explore further the interplay between autonomy support, intrinsic motivation and cognitive strategy use during Physics learning in lower secondary schools. We hypothesised that members in the distinct identified profiles differed in their perceived autonomy support and intrinsic motivation, with students in profiles indicating high-order strategies reporting highest levels of both intrinsic motivation and perceived teacher autonomy support.

6.2 Methods

6.2.1 Participants

Following recommendations by Krejice and Morgan (1970), 579 9^{th} grade students were randomly selected from 6 schools Central Uganda. However, data from six female students was excluded from further analyses due to students' failure to provide written consent. Consequently, data from 573 students were used for analyses. Given that gender was a binary variable, the majority of the students were females (n = 321, 56%). Most of the students aged between 14 and 15 years (Mean = 14.3, SD = 1.51). Of all students, 50.9% resided home. Being a day scholar is characteristic typical of most secondary school going children in semi-urban areas of Uganda coming from low economic status families.

6.2.2 Procedure and Ethics

Initially, ethical clearance was sought from Mbarara University of Science and technology and Universität Potsdam Research Ethical Committees. Then, school head teachers of the selected schools were approached to obtain permission allowing us access to grade 9 students and Physics teachers. Upon in-depth discussions about the purpose, significance, and data collection and protection procedures of the study during the information-giving session, students provided written consent to voluntarily participate in the study. Subsequently, anonymised questionnaires were administered to the participants during a Physics class, in the presence of at least one of the researchers and a research assistant.Participants required approximately 30 minutes to complete the questionnaire.

6.2.3 Instrument

We used a self- reported questionnaire to collect data. This instrument consisted of four sections. In the first section, students' socio-demographic characteristics e.g., gender, age, residence status, and highest education level of their parents were elicited. Below, we briefly discuss each of the remaining three sections.

Cognitive and Metacognitive Learning Strategies Use

In the second section, three different aspects of cognitive learning strategies i.e., rehearsal, elaboration, critical thinking, and metacognitive self-regulation were assessed using the cognitive and metacognitive learning strategies section of the Motivated Strategies Learning Questionnaire (MSLQ; Pintrich et al., 1991). The cognitive and metacognitive learning strategies sections of the MSLQ were selected because they incorporate various categories of learning strategies ranging from surface-level learning strategies e.g., memorization to deep-level learning strategies e.g., self-testing, critical thinking, and task analysis. Items were modified to suite the study context by replacing "class" with "Physics class". An example of a modified rehearsal strategy item includes "I memorize key words to remind me of important concepts in the Physics class". All items were answered on a 5-point Like rt scale ranging from 7 (very true of me) to 1 (not at all true for me). Results of the confirmatory factor analysis on the four-factor model used on the present student sample produced good model fit indices (see Table 6.1). Reliability coefficients and descriptive statistics of the used subscales are presented in Table 6.2.

Perceived Autonomy Support

The third section assessed students' perceived teacher's autonomy support using a 15-item section that we adapted from Williams and Deci (1996) Learning Climate Questionnaire (α = 0.91). Sample items included "I feel that my physics teacher provides me choices and options" and "my physics teacher shows confidence in my ability to do well in physics tests". Students scored the items on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Following a confirmatory factor analysis, one item "I feel able to share my feelings with my physics teacher" had a factor loading less than 0.40. Consequently, this item was excluded. Fit indices, descriptive statistics and reliability coefficient are reported in Tables 6.1 and 6.2.

Intrinsic Motivation

Lastly, the fourth section assessed Students' intrinsic motivation for Physics learning. We used a 5-item intrinsic motivation section from the adapted Physics version (Kwarikunda et al., 2020) of the Science Motivation Questionnaire II (Glynn et al., 2011). Items were answered on a 5-point Likert scale with anchors ranging from never (1) to always (5). Fit indices from a confirmatory factor analysis of the intrinsic motivation section, internal consistency as indexed by Cronbach's alpha, and descriptive statistics are indicated in Tables 6.1 and 6.2.

6.2.4 Data Analyses

Preliminary Analyses

Data were initially screened for missing values, outliers, normality, sampling adequacy, and sphericity. Due to its efficiency compared to other methods such as list-wise deletion (Wang & Wang, 2012), Full-Information-Maximum likelihood estimator was used to handle the 0.5% missing values. Using the Shapiro-Wilk test, normality distribution of the data was checked. Data passed the normality test, since a non-significant value (p = 0.78) was obtained. Then, Kaiser-Meyer-Olkin measure of sampling adequacy was conducted, which Data passed (KMO

= 0.93). To test for sphericity, Bartlett's test was done. A significant Chi square value (χ^2= 2789.65, $p < 0.05$) was obtained indicating adequate quality of the correlation matrix of the items. Following the above tests, Confirmatory Factor Analysis (CFA) was conducted on each of the instrument sections. One item "I feel able to share my feelings with my physics teacher" with a factor loading of less than 0.40 was deleted from the model. Following Hu and Bentler (1999) model fit criteria (Comparative Fit Index and Tucker-Lewis Index $\geq$ 0.90, Standardized Root Mean Square Residual $\leq$ 0.08, and Root Mean Square Error of Approximation $\leq$ 0.06), data were of good fit (see Table 6.1). Cronbach's alphas, as an index of internal reliability, were also examined for each section of the instrument. Pearson's correlation coefficients were also noted (see Table 6.2).

Prior to latent profile analyses, we also conducted independent samples t-tests using SPSS version 20 to test for gender variations in students' cognitive learning strategy use. We could not find any variable-centered research in gender differences across cognitive strategy use during Physics learning in Uganda. Thus, we conducted these tests to provide us with a variable-centered result that would complement the person-centered approach. In addition, Cohen's d effect sizes (Cohen, 1988) were examined. Effect sizes were interpreted as; small if $\leq$ 0.20, medium if 0.21 $\leq$ d $\leq$ 0.50 or high if 0.51 $\leq$ d $\leq$ 0.80 (Cohen, 1988).

6.2.5 Latent Profile Analyses (LPA)

As recommended by Hickendorff et al. (2018) colleagues , we used the 3-step approach of LPA. In the first step, a series of LPA models with an increasing number of latent profiles whilst comparing ***k*** profile model with the ***k-1*** profile model were conducted to determine the number of profiles. The best profile model solution was reached using a combination of several model fit criteria. Firstly, information-theoretic methods such as Akaike's Information Criterion (AIC; Akaike, 1974), Bayesian Information Criterion (BIC; Schwarz, 1978), and sample - size adjusted BIC (ABIC; Sclove, 1987) were used. A model that produces smaller values of AIC, BIC and ABIC has better fit (Wang & Wang, 2012).

Secondly, likelihood ratio statistic tests such as Lo-Mendell-Rubin likelihood ratio test

(LMR), ad hoc adjusted LMR, and boot strap likelihood ratio test (BLRT; McCutcheon, 1987) that assess improvement in neighboring class models by comparing normal mixture distribution of the ***k*** class against an alternative ***k-1*** class were also used. A small probability value ($p < 0.05$) implies that there is statistically significant improvement in the ***k*** profile model than in the ***k-1*** profile model. Thus, the ***k*** profile model which is of better fit to the data is accepted, whilst the ***k-1*** profile model is rejected (Wang & Wang, 2012). Basing on results from simulation studies, BLRT performs better in estimating the best model fits as compared to other likelihood tests (Berlin, Williams, & Para, 2013). Thus we prioritized BLRT results before we could use other likelihood ratio statistics.

Thirdly, entropy-based criterion which assess the quality or adequacy of latent profile membership were used. A normalized entropy value greater than 0.8, indicates that the latent profiles are highly discriminating (Wang & Wang, 2012). We further examined closely the posterior classification probabilities and profile size distribution (as suggested by Wang & Wang, 2012). A model, whose profiles' posterior classification probability values are greater than 0.85, indicate adequate membership allocation. A profile with size of $< 5\%$ is problematic, and it is recommended to reject the model with such a profile size. Vermunt (2010) recommends further examination of the profiles in respect to the theory underlying the study such that the profiles can be interpreted and explained by the study theory. This is important in identifying each of the processes in the second step.

Gender, perceived Autonomy Support and Intrinsic Motivation as predictors of Profile membership

After selecting the number of profiles, the third step was to examine the predictive relations of students' gender, perceived teacher autonomy support and intrinsic motivation and the likelihood of membership into the various profiles. We conducted multinomial logistic regression analyses. At this step, these variables were incorporated as covariates in model estimation using the auxiliary command and LPA were rerun. The inclusion of the covariates at this stage in the model does not affect profile allocation, and it helps to limit type 1 errors

(Vermunt, 2010) which are common when using the 1-step LPA approach. Regression coefficients and odd ratios were reported. Latent profile analyses were conducted in Mplus 8 (L. K. Muthén & Muthen, 2017).

6.3 Results

Preliminary Results

Data passed tests of sampling adequacy (KMO = 0.93) and sphericity (χ^2 = 2789.65, $p < 0.05$). Confirmatory factor analyses revealed acceptable fit indices, supporting the factor validity of each of the sections of the measures we used with our study sample (see Table 6.1). Factor loadings of the items were above 0.65. Results of the tests of measurement invariance of the learning strategy use section of the instrument used across gender indicate that learning strategy use section of the instrument showed strong measurement invariance (See Table 6.2). Thus, comparisons of means across gender could be carried out in the next steps. On assessing the internal reliabilities of the sections (subscales) of the questionnaire we used, Cronbach's coefficients were satisfactory (ranging from 0 .70 to 0.90; see Table 6.3).

Table 6.1

Fit Indices from Confirmatory Factor Analyses of each Section the Latent Variables used.

	χ^2 /df	CFI	TLI	RMSEA	SRMR
Teacher autonomy support	1.34	0.93	0.95	0.03	0.05
Intrinsic motivation	2.11	0.92	0.93	0.06	0.04
Cognitive learning strategy use	1.52	0.93	0.94	0.05	0.04

6.3.1 Descriptive Statistics and Correlations between the study variables

Means and standard deviations of the variables included in the model were examined and presented in Table 6.3. The mean scores for perceived teacher autonomy support and intrinsic motivation were mid-range. Of the cognitive learning strategies used, the mean score of critical thinking was the lowest in our sample whilst that of elaboration was the highest.

Table 6.3 includes also the correlations between our study variables. As expected, all the study variables were significantly positively associated with each other, with strong associations between perceived teacher autonomy support and intrinsic motivation. Within the cognitive learning skills used, metacognition was strongly associated with rehearsal. One the other hand, students reported to use mostly elaboration and metacognition. On the other hand, critical thinking was the least used cognitive learning strategy.

Table 6.2

Tests of Measurement Invariance of the Cognitive and Metacognitive Learning Strategies use scale across Gender.

Level of measurement invariance	Model fit				Compared model	Results of model comparison	
	χ^2 /df	CFI	TLI	RMSEA		Δ CFI	Δ RMSEA
Female	1.942	0.963	0.957	0.053	-	-	-
Male	1.933	0.962	0.950	0.057	-	-	-
Configural invariance	2.046	0.981	0.961	0.055	-	-	-
Metric invariance	2.061	0.986	0.969	0.052	configural	0.00	0.003
Scalar Invariance	2.069	0.986	0.971	0.050	metric	-0.002	0.002
Strict invariance	2.072	0.991	0.978	0.049	scalar	-0.001	0.001

6.3.2 Latent Profile Analyses

Results of the latent profile analyses were presented in Table 4, Table 5, and Figure 1.

Model Selection

Generally, AIC and BIC decreased with increasing number of profiles in the model. Apart from the 6-profile model, entropy values were higher than 0.80. Following recommendations by Asparouhov and Muthén (2007), we run latent profile analyses until we obtained a non-significant p value for BLRT for ***K*** = 6. However, the 5-profile model was also rejected due to possession of a profile with profile size of less than 5% (see Table 6.4) leaving four models choose from. Although the LMR LR and aLMRT rejected the 4-profile model, we chose this model based on it's (a) significant BLRT (Asparouhov & Muthén, 2007), (b) classification probabilities (Nagin, 2005), and theoretical interpretation of the profiles (Wang and Wang, 2012)

Table 6.3

Means and Standard Deviations, Correlations between measured variables, and Reliability Coefficients for each subscale.

Variable	Mean (SD)	1	2	3	4	5	6	7
1. Perceived autonomy support	5.28 (1.28)	**0.90**						
2. Intrinsic motivation	2.73 (0.92)	0.52**	**0.73**					
(Meta) Cognitive learning skills								
3.Rehearsal	5.45 (1.19)	0.33**	0.25**	**0.87**				
4. Organisation	5.28 (1.06)	0.28**	0.23**	0.62**	**0.84**			
5.Elaboration	5.33 (1.27)	0.35**	0.47**	0.64**	0.54**	**0.88**		
6.Critical thinking	4.63 (1.29)	0.37**	0.46**	0.63**	0.61**	0.61**	**0.82**	
7.Metacognition	5.27 (1.01)	f 0.39**	0.47**	0.67**	0.63**	0.65**	0.65**	**0.90**

Note. nf, free parameters; Log L, model log likelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC; LMR LR, Lo-Mendell-and Rubin likelihood ratio test; aLMRT, adjusted Lo-Mendell-Rubin likelihood ratio test; BLRT, bootstrap likelihood ration Test. Bold indices are for the selected model.

Table 6.4

Model Fit Indices for the models with number of Latent Profiles ranging from 1 to 6.

Fit index	Model					
	1-profile	2-profile	3-profile	4-profile	5-profile	6-profile
nf	10	16	22	28	34	40
Log L	-3226.49	-2768.99	-2678.75	-2590.87	-2498.14	-2541.65
AIC	6172.98	5464.19	5238.11	5254.64	5090.67	5003.94
BIC	6216.02	5520.98	5287.64	5319.62	5212.37	5168.33
ABIC	6180.23	5481.23	5237.84	5136.78	5165.02	5073.97
Entropy	-	0.84	0.86	0.80	0.816	0.79
LMR LR	-	0.0004	<0.0001	0.43	0.015	0.41
$_a$LMRT	-	0.0005	<0.0001	0.44	0.016	0.44
BLRT	-	<0.0001	<0.0001	<0.0001	<0.0001	0.46
<5% Class size	-	0	0	0	1	2

Note. nf, free parameters; Log L, model log likelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC; LMR LR, Lo-Mendell-Rubin likelihood ratio test; aLMRT, adjusted Lo-Mendell-and Rubin likelihood ratio test; BLRT, bootstrap likelihood ration Test. Bold indices are for the selected model.

Table 6.5

Final Cluster Counts, Profile Size, and Classification Probabilities for most likely Latent Profile Membership for the different Models.

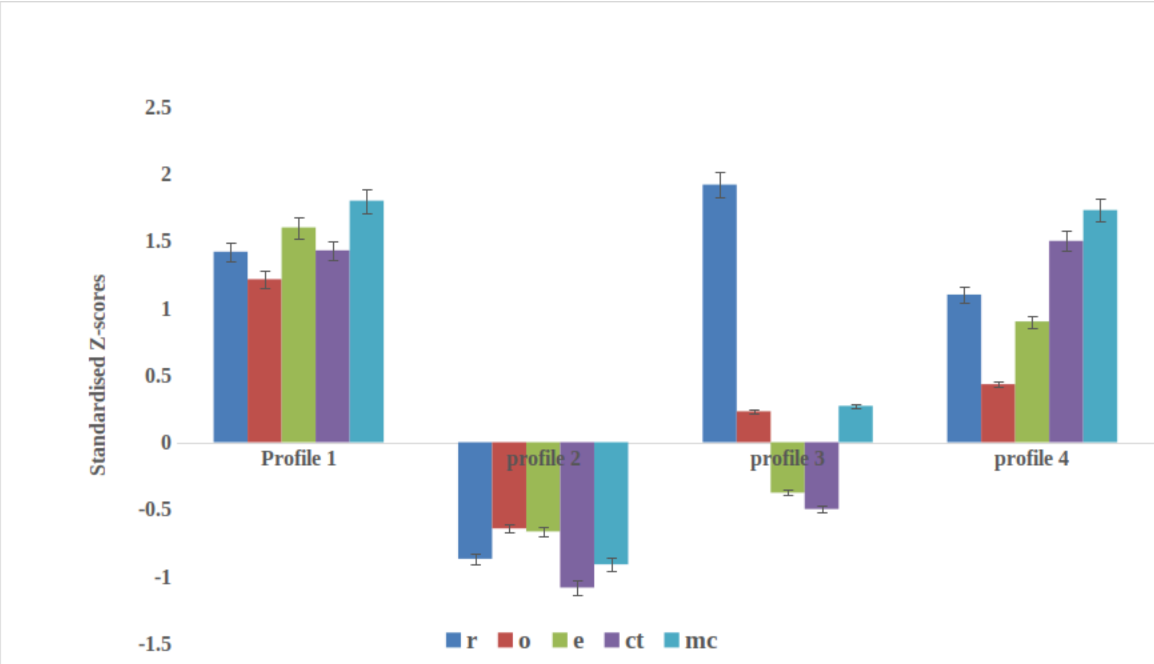
Model	Profile size	Classification probabilities				
		1	2	3	4	5
Two-profile						
1, n = 222	38.8%	0.98	0.02			
2, n = 351	61.2%	0.03	0.97			
Three-profile						
1, n = 76	13.4%	0.96	0.04	0.00		
2, n = 233	40.6%	0.05	0.91	0.04		
3, n = 264	46.0%	0.00	0.04	0.96		
Four-profile						
1, n = 152	**26.5%**	**0.94**	**0.06**	**0.00**	**0.00**	
2, n = 62	**10.9%**	**0.09**	**0.87**	0.03	**0.00**	
3, n = 204	**35.6%**	**0.00**	**0.01**	**0.89**	**0.09**	
4, n = 155	**27.0%**	**0.05**	**0.00**	**0.05**	**0.90**	
Five-profile						
1, n = 9	1.6%	0.94	0.06	0.00	0.00	0.00
2, n = 68	11.8%	0.03	0.93	0.00	0.04	0.00
3, n = 191	33.4%	0.00	0.00	0.83	0.09	0.08
4, n = 171	29.9%	0.00	0.02	0.09	0.89	0.00
5, n = 134	23.3%	0.00	0.00	0.13	0.00	0.87

Profile Composition and Identification

As presented in Table 6.4, the model that fit in our data indicates existence of four distinct learner profiles in our data sample. Each profile's standardized z-scores of rehearsal, organization, elaboration, critical thinking, and metacognitive self-regulation were graphically represented in Figure 6.1 below.

Figure 6.1

Z Scores for the different Cognitive and Metacognitive Learning Strategies used in the Four Profiles.



Note. r, rehearsal; o, organization; e, elaboration; ct, critical thinking; mc, metacognitive self-regulation.

The first profile (n = 152, 26.5%) consisted of students with the highest mean scores on elaboration, organization, and critical thinking. Also, these students reported high levels of metacognitive self-regulation skills. Thus, this students' learner profile was labelled as the competent strategy users' profile. With the smallest student population (n = 62, 10.9%), the second profile comprised of students whose mean scores of usages of the cognitive and metacognitive strategies were the lowest (all z –scores were negative). We named this profile the struggling strategy user profile. The largest student population (n = 204, 35.6%) were categorized in the third profile. Students in this profile reported high mean scores on surface learning skills (rehearsal, M = 1.94), low z-score on organisation, elaboration and critical thinking strategies, and slightly above-the-mean score on metacognitive self-regulation skills. Thus, this profile was named surface-level learners. The last profile (n = 155, 27%) comprised of students that demonstrated use of complex high-order cognitive learning strategies compared to their counterparts. Consequently, this profile was identified as deep-level leaners' Profile.

6.3.3 Profile membership Likelihood based on Gender, perceived Autonomy Support and Intrinsic Motivation

Prior to latent profile analysis, we conducted paired t-tests to assess gender differences in the usage of the cognitive and metacognitive learning strategies in the whole sample. As presented in Table 6.6, female students used elaboration (t =2.21, p =0.02, d = 0.47) and organization (t = 1.93, p = 0.03, d = 0.47) strategies more likely than the male students.

Table 6.6

Gender Differences in Cognitive Learning Strategies used.

	Mean (SD)		t	p
	Male	Female		
Rehearsal	5.08 (1.32)	5.05 (1.27)	0.26	0.47
0rganisation	5.03 (1.30)	5.24 (1.29)	1.93	**0.03** *
Elaboration	5.09 (1.34)	5.36 (1.16)	-2.21	**0.02***
Critical thinking	4.79 (1.30)	4.69 (1.28)	0.69	0.47
Metacognition	5.16 (1.06)	5.22 (0.93)	-0.61	0.54

$*p < 0.05$

In terms of profile membership, female students appeared to be 2.4-2.7 times more likely than the male students to be members of the competent user and surface-level learner profiles relative to the struggling user and deep-level learner profiles. Regarding perceived teacher autonomy support and intrinsic motivation, higher levels of perceived teacher autonomy support and intrinsic motivation increased the likelihood of membership into the competent user and deep-level learner profiles relative to the other profiles. One the other hand lower levels of intrinsic motivation and perceived autonomy support predicted an increased likelihood of membership into the struggling user profile (see Table 6.7).

Table 6.7

Results from Multinomial Logistic Regressions of Predictors of Profile Memberships.

	Profile 1 vs Profile 2		Profile 2 vs Profile 3		Profile 3 vs Profile 4	
	Coef (SE)	OR	Coef (SE)	OR	Coef (SE)	OR
Gender	0.83 (0.41) **	2.43	0.64 (0.39)	1.14	**1.03 (0.41) ****	**2.53**
Perceived Autonomy Support	**1.27 (0.21) ****	**2.87**	**-0.57 (0.17) ****	**0.63**	**-0.96 (0.16) ****	**2.11**
Intrinsic motivation	**1.07(0.16) ****	**2.42**	**-0.42 (0.39) ****	**1.02**	**-0.63 (0.15) ****	**2.01**
	Profile 1 vs Profile 3		Profile 2 vs Profile 4		Profile 1 vs Profile 4	
	Coef (SE)	OR	Coef (SE)	OR	Coef (SE)	OR
gender	-0.26 (0.36)	0.94	1.02(0.33)	1.47	**0.91(0.38) ****	**2.74**
Perceived Autonomy Support	**1.01(0.13) ****	**1.24**	**-1.26 (0.41) ****	**2.03**	**1.17(0.18) ****	**2.41**
Intrinsic motivation	**1.39 (0.21) ****	**1.28**	**-0.63 (0.19) ****	**2.13**	**1.48 (0.41) ****	**2.95**

$**p < 0.05$

Note. Profile1, Competent user learner profile; Profile 2, Struggling User learner profile; Profile 3, surface-level learner profile; Profile 4, deep-level learner profile; Coef, Coefficients; SE, Standard error of the coefficient; OR, odds ratio. The Coef and OR reflects the effects of the predictors on the membership likelihood into the first listed profile relative to the second listed profile.

6.4 Discussion

An effective education system aims at producing independent, autonomous and efficient life- long learners. For effective recommendations and interventions, tremendous amount of educational research is needed to understand the learning process of students, especially their repertoire of learning strategies. Several studies have been conducted to investigate learning strategy use at different educational levels. Nevertheless, research on cognitive strategy use and learner profiles in lower secondary school remains scarce. Moreover, the few studies that do exist have examined self-regulation in general Science, text-reading using cluster analysis. Little is known about the occurrence of learner profiles with regard to their cognitive learning strategy use during Physics learning in lower secondary school. Thus, the present study investigated the existence of learner profiles using latent profile analysis. We included metacognition as one of our latent profile indicators due to its usefulness for academic achievement (Akyol et al., 2010; Pintrich, 2000). Further, differences in gender, intrinsic motivation, and perceived autonomy support within the identified profiles were investigated to deepen our understanding of individual differences in learners' cognitive strategy use.

Prior to the latent profile analyses, we closely examined the mean score for each cognitive learning strategy used in our sample. Findings revealed that lower secondary school students reported use of mostly rehearsal, elaboration, and metacognitive self-regulation learning strategies during Physics learning, whilst, critical thinking strategies were least used. This could be due to limited knowledge acquired at this level. Perhaps students perceive Physics information at this level as still new and thus they cannot seem to find how it could be related to solving daily problems. Given that elaboration strategies assist learners in transferring acquired knowledge to working memory (Jurik et al., 2014), high levels of elaboration use help learners to manipulate knowledge and summarise material (Karlen, 2016). Since Physics is composed of numerous equations, graphs, and formulae, students tend to comprehend such tasks through elaboration. Through metacognition, learners plan, paraphrase and self- evaluate their learning. It is very common in Uganda to find students using Uganda National Examinations Board

(UNEB) question banks as reference questions during Physics revision. In fact, students begin using these booklets as early as their first term in secondary school so that they can test how much they have learnt according to the previously set UNEB questions for the topics they have covered. Whereas such questions can be used for revision guidance, there have been reported tendencies of students relying only on such material during learning rather than textbooks that require a lot of critical analysis, summarization, paraphrasing and problem solving, skills that could further promote critical thinking. Nevertheless, the use of mostly rehearsal and elaboration strategies during learning was also reported among high school students in; Turkey during science learning (Akyol et al., 2010), Uganda during biology (Ekatushabe et al., 2021), Philippines (King & Areepattamannil, 2014). Based on our study findings and the fore mentioned studies, elaboration strategies could be the basic learning strategies used by most high school science students in developing countries.

Using latent profile analysis, four distinct profiles of students with regard to their cognitive learning strategy use during Physics learning were unveiled. In terms of the number of profiles, similar findings were found in previous studies (e.g., Karlen, 2016; Merchie & Van Keer, 2014; Zheng et al., 2020). Surface-level learners were the most preferable profile. These learners reported to use mostly rehearsal than critical thinking and metacognition. However, we could not identify these learners as memorisers (as in Merchie and Van Keer, 2014) or as rote learners (as in Niemivirta, 1997) because they had reported an average use of elaboration which enhances minimal interconnection of newly-learned information to pre-existing knowledge (Pintrich et al., 1993). Identifying them as memorisers would imply that they used only rehearsal, which was not the case here. On the other end of the spectrum lie the struggling strategy users. This profile was the least preferred profile among all the four profiles. Although students in this profile used all the cognitive learning strategies, their frequency of use was below the sample average. Perhaps, these learners could be using other learning strategies such as highlighting important phrases and underlining or circling important formulae and points, strategies that were not included in the scope of the study instruments. Unlike the competent strategy users, who also scored quantitatively highly on all cognitive learning strategies, deep-level learners reported to use mostly critical thinking and metacognition than rehearsal and elaboration given that the mean score was also above average but not like in surface- level learners or competent strategy users. Several studies (e.g., Karlen, 2016) have highlighted the importance of critical thinking and metacognition for academic achievement. As to whether the frequency (competent strategy users) or quality (deep-level learners) cognitive strategy use is superior to performance (Karlen, 2016), we have no opinion since we were not able to assess such a relationship due to lack of achievement data in Physics. However, further study in this direction is recommended.

Similarly, our quantitative profiles were closely related to those in Ugandan teacher trainees whilst using the same questionnaire (see Muwonge et al., 2020). This could be indicative that probably specific cognitive learning strategies are emphasized by teachers during instruction. Perhaps when teacher trainees become teachers, they emphasise and encourage their students to use a certain set of cognitive learning strategies that the teacher trainees themselves found more useful whilst during their lower secondary school physics lessons.

To deepen our understanding of individual differences in the distinct profiles, we conducted tests for gender, intrinsic motivation and perceived autonomy support across the profiles. As expected, significant gender differences were recorded in use of organization and elaboration strategies in favor of girls. Contrary to OECD (2010) findings, girls preferred to use elaboration strategies. Although boys preferred use of rehearsal, we disagree that boys are necessarily rote learners Niemivirta (1997) . This is because, in our sample, boys reported a higher mean score of critical thinking than girls. Perhaps, boys preferred to use rehearsal strategies while learning what they perceived as simple Physics tasks such as memorization of formulae and theorem, definition of key terms, and use critical thinking for what they perceive as mentally challenging Physics tasks such as manipulation of apparatus in laboratories during experiments that prove a theorem or given concept. In regard to profile membership, girls were preferably categorized as competent strategy users and surface-level learners. The high frequency of female competent strategy users conforms to previous study findings that girls are more knowledgeable of different learning strategies (OECD, 2010) and utilize more strategies than their male counterparts (Rogiers et al., 2019) during Science learning. Contrary to

Niemivirta (1997) there were more female than male students in a profile with students who use more superficial learning strategies during physics learning. The presence of more girls than boys in the surface-level learners' profile could be perhaps that girls use more overt strategies to understand and remember information (OECD, 2010; Slotte et al., 2001. Also, the fact that Physics contains a lot of mathematics applications, formulae, graph work, and theories, possibly girls with mathematics anxiety, bias and boredom could transfer such affective factors and negative emotions towards physics learning (Hunt et al., 2021), which in turn could influence their choice for use of surface- level cognitive learning strategies.

It is worrisome that as early as lower secondary school, a fairly large group of students found difficulty using cognitive strategies (struggling strategy users). Immediate attention should be given to such students before advancement and complexity of knowledge takes place. If the gender gap in Physics achievement and Physics career is to be bridged,teachers should give clear, explicit, and direct instructions about cognitive strategy use during instruction, with more emphasis on deep-level learning strategies especially to the girls.

As hypothesised, struggling strategy users reported least score of intrinsic motivation and perceived less autonomy support. Given that autonomy support is very important for the development of intrinsic motivation (Ratelle et al., 2007a; Vansteenkiste et al., 2009), such a pattern in struggling strategy users is not surprising. Perhaps these students rely more on their Physics teachers or peers to plan, summarise, monitor, and supervise their learning activities. Such a pattern in struggling strategy users could be indicative of these students using extrinsic (controlled) motivation during Physics learning (Ratelle et al., 2007b). What is intriguing is the difference in perceived autonomy support and intrinsic motivation between the competent strategy users and deep-level learners. We expected deep-level learners to have high scores of both perceived autonomy support and intrinsic motivation, which was not the case. Further study could be undertaken to understand such a pattern.

6.4.1 Limitations and Recommendations for future studies

The findings of the present study should be interpreted in light of the limitations discussed below. Recommendations for further studies have also been highlighted. First, data were collected using self-report questionnaires. To further complement the quantitative findings in students' cognitive learning strategy use, use of in-depth methods such as review of students' Physics learning diaries is recommended. From these diaries, perhaps other patterns of different cognitive learning repertoires and strategies can be unveiled.

Secondly, the cross-sectional nature of the present study precludes inferring causality. Moreover, stability of the profiles throughout the remaining years of High-School is not known. Thus, longitudinal explorations of the stability and evolution of learners' profiles over time is recommended.

Lastly, our study focused on Physics learning only. Future studies could explore cognitive learning strategy use in other Science domains such as Biology and Chemistry. Also, due to lack of data regarding participants' Physics performance, it was not possible to establish the relationship between the profiles and Physics performance. Thus, an investigation into the relationships between the profiles and students' Physics achievement is highly recommended.

6.5 Conclusions

Results from the present study have revealed that unlike critical thinking, students use mostly elaboration and metacognition during Physics learning. Person-centered analyses revealed four distinct learner profiles with respect to their cognitive learning strategy use among lower secondary school students. In addition, these profiles significantly differ in their intrinsic motivation and perceived autonomy support. Specifically, competent strategy users reported receiving more autonomy support from their Physics teachers than their counterparts, while the highest levels of intrinsic motivation were reported among deep-level learners. Additionally, significant gender differences where noted in two profile memberships. Girls were more likely to be categorized as competent strategy users and surface-level learners. Thus, teachers should use instructions that emphasize deep-learning cognitive skills in girls in the first years of secondary school.

Ethical Approval

We confirm that the present research was conducted in accordance with the relevant ethical guidelines and regulations for human participants. Ethical approval for the study was obtained from Mbarara university of Science and Technology Research Ethics Committee (no.86/2019) and the Universität Potsdam Research Ethics Committee. Approval from the latter committee was necessary for legal reasons

Informed Consent

Participants provided written consent without coercion.

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References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/TAC.1974.1100705

Akyol, G., Sungur, S., & Tekkaya, C. (2010). The contribution of cognitive and metacognitive strategy use to students' science achievement. *Educational Research and Evaluation*, *16*(1), 1–21.

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International journal of science education*, *30*(8), 1075–1093.

Bidjerano, T. (2005). Gender differences in self-regulated learning. *Online Submission*.

Bouckenooghe, D., Cools, E., De Clercq, D., Vanderheyden, K., & Fatima, T. (2016). Exploring the impact of cognitive style profiles on different learning approaches: Empirical evidence for adopting a person-centered perspective. *Learning and Individual Differences*, *51*, 299–306.

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental and Science Education*, *6*(2), 141–159.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Lawrence Erlbaum.

Corpus, J. H., & Wormington, S. V. (2014). Profiles of intrinsic and extrinsic motivations in elementary school: A longitudinal analysis. *The Journal of Experimental Education*, *82*(4), 480–501.

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, *11*(4), 227–268.

Dowson, M., & McInerney, D. M. (1998). Cognitive and motivational determinants of students' academic performance and achievement: Goals, strategies, and academic outcomes in focus.

Duncan, T. G., & McKeachie, W. J. (2005). The making of the motivated strategies for learning questionnaire. *Educational psychologist*, *40*(2), 117–128.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, *53*(1), 109–132.

Ekatushabe, M., Kwarikunda, D., Muwonge, C. M., Ssenyonga, J., & Schiefele, U. (2021). Relations between perceived teacher's autonomy support, cognitive appraisals and boredom in physics learning among lower secondary school students. *International Journal of STEM Education*, *8*(1), 1–15.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire ii: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159–1176.

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion*, *34*(4), 371–383.

Heikkilä, A., Lonka, K., Nieminen, J., & Niemivirta, M. (2012). Relations between teacher students' approaches to learning, cognitive and attributional strategies, well-being, and study success. *Higher Education*, *64*(4), 455–471.

Hickendorff, M., Edelsbrunner, P. A., McMullen, J., Schneider, M., & Trezise, K. (2018). Informative tools for characterizing individual differences in learning: Latent class, latent profile, and latent transition analysis. *Learning and Individual Differences*, *66*, 4–15.

Hong, W., Bernacki, M. L., & Perera, H. N. (2020). A latent profile analysis of undergraduates' achievement motivations and metacognitive behaviors, and their relations to achievement in science. *Journal of Educational Psychology*, *112*(7), 1409.

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1–55.

Hunt, T., Muwonge, C., Ashraf, F., Asanjarani, F., Kotera, Y., Vione, K., Sheffield, D., Mir, R., & Waldron, M. (2021). Psychological barriers in maths education: Insights from iran, pakistan, and uganda. https://doi.org/10.13140/RG.2.2.36106.59844/1

Jurik, V., Gröschner, A., & Seidel, T. (2014). Predicting students' cognitive learning activity and intrinsic learning motivation: How powerful are teacher statements, student profiles, and gender? *Learning and individual differences*, *32*, 132–139.

Karlen, Y. (2016). Differences in students' metacognitive strategy knowledge, motivation, and strategy use: A typology of self-regulated learners. *The Journal of Educational Research*, *109*(3), 253–265.

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, *54*(5), 586–614.

King, R. B., & Areepattamannil, S. (2014). What students feel in school influences the strategies they use for learning: Academic emotions and cognitive/meta-cognitive strategies. *Journal of Pacific Rim Psychology*, *8*(1), 18–27.

Kusurkar, R. A., & Croiset, G. (2015). Autonomy support for autonomous motivation in medical education. *Medical education online*, *20*(1), 27951.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in uganda. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 435–446.

Linn, M. C. (2000). Designing the knowledge integration environment. *International Journal of Science Education*, *22*(8), 781–796.

Liu, W. C., Wang, C. K. J., Kee, Y. H., Koh, C., Lim, B. S. C., & Chua, L. (2014). College students' motivation and learning strategies profiles and academic achievement: A self-determination theory approach. *Educational Psychology*, *34*(3), 338–353.

Manganelli, S., Cavicchiolo, E., Mallia, L., Biasi, V., Lucidi, F., & Alivernini, F. (2019). The interplay between self-determined motivation, self-regulated cognitive strategies, and prior achievement in predicting academic performance. *Educational Psychology*, *39*(4), 470–488.

McCutcheon, A. L. (1987). *Latent class analysis*. Sage.

Meece, J. L., & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *33*(4), 393–406.

Merchie, E., & Van Keer, H. (2014). Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills. *Learning and Individual Differences*, *32*, 193–203.

Merchie, E., Van Keer, H., & Vandevelde, S. (2014). Development of the text-learning strategies inventory: Assessing and profiling learning from texts in fifth and sixth grade. *Journal of Psychoeducational Assessment*, *32*(6), 533–547.

Metallidou, P., & Vlachou, A. (2007). Motivational beliefs, cognitive engagement, and achievement in language and mathematics in elementary school children. *International journal of psychology*, *42*(1), 2–15.

Muthén, B., & Muthén, L. K. (2000). Integrating person-centered and variable-centered analyses: Growth mixture modeling with latent trajectory classes. *Alcoholism: Clinical and experimental research*, *24*(6), 882–891.

Muthén, L. K., & Muthen, B. (2017). *Mplus user's guide: Statistical analysis with latent variables, user's guide*. Muthén & Muthén.

Muwonge, C. M., Ssenyonga, J., Kibedi, H., & Schiefele, U. (2020). Use of self-regulated learning strategies among teacher education students: A latent profile analysis. *Social Sciences & Humanities Open*, *2*(1), 100037.

Niemivirta, M. (1997). Gender differences in motivational-cognitive patterns of self-regulated learning.

Ning, H. K., & Downing, K. (2015). A latent profile analysis of university students' self-regulated learning strategies. *Studies in Higher Education*, *40*(7), 1328–1346.

OECD. (2010). *Pisa 2009 results: Learning to learn. student engagement, strategies and practices (vol. iii)*.

Pintrich, P. R., et al. (1991). A manual for the use of the motivated strategies for learning questionnaire (mslq).

Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International journal of educational research*, *31*(6), 459–470.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In *Handbook of self-regulation* (pp. 451–502). Elsevier.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (mslq). *Educational and psychological measurement*, *53*(3), 801–813.

Pintrich, P. R., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In *Development of achievement motivation* (pp. 249–284). Elsevier.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: A systematic review of 12 years of educational research. *Studies in science education*, *50*(1), 85–129.

Purdie, N., Hattie, J., & Douglas, G. (1996). Student conceptions of learning and their use of self-regulated learning strategies: A cross-cultural comparison. *Journal of educational psychology*, *88*(1), 87.

Ratelle, C. F., Guay, F., Vallerand, R. J., Larose, S., & Senécal, C. (2007a). Autonomous, controlled, and amotivated types of academic motivation: A person-oriented analysis. *Journal of educational psychology*, *99*(4), 734.

Ratelle, C. F., Guay, F., Vallerand, R. J., Larose, S., & Senécal, C. (2007b). Autonomous, controlled, and amotivated types of academic motivation: A person-oriented analysis. *Journal of educational psychology*, *99*(4), 734.

Rogiers, A., Merchie, E., & Van Keer, H. (2019). Learner profiles in secondary education: Occurrence and relationship with performance and student characteristics. *The Journal of Educational Research*, *112*(3), 385–396.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, *55*(1), 68.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299–323.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in science education*, *36*(1), 111–139.

Schunk, D., Pintrich, P., & Meece, J. (2008). Motivation in education 3rd ed upper saddle river.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics*, 461–464.

Sclove, S. L. (1987). Application of model-selection criteria to some problems in multivariate analysis. *Psychometrika*, *52*(3), 333–343.

Sjøberg, S., & Schreiner, C. (2010). *The rose project. an overview and key findings. rose publications.*

Slotte, V., Lonka, K., & Lindblom-Ylänne, S. (2001). Study-strategy use in learning from text. does gender make any difference? *Instructional Science*, *29*(3), 255–272.

Stolk, J., & Harari, J. (2014). Student motivations as predictors of high-level cognitions in project-based classrooms. *Active Learning in Higher Education*, *15*(3), 231–247.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of educational psychology*, *101*(3), 671.

Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political analysis*, *18*(4), 450–469.

Wang, J., & Wang, X. (2012). *Structural equation modeling with mplus: Methods and applications*. Wiley.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of personality and social psychology*, *70*(4), 767.

Wolters, C. A., & Pintrich, P. R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, english, and social studies classrooms. *Instructional science*, *26*(1), 27–47.

Wormington, S. V., Corpus, J. H., & Anderson, K. G. (2012). A person-centered investigation of academic motivation and its correlates in high school. *Learning and Individual Differences*, *22*(4), 429–438.

Zhao, J., & Qin, Y. (2021). Perceived teacher autonomy support and students' deep learning: The mediating role of self-efficacy and the moderating role of perceived peer support. *Frontiers in psychology*, *12*, 2177.

Zheng, J., Xing, W., Zhu, G., Chen, G., Zhao, H., & Xie, C. (2020). Profiling self-regulation behaviors in stem learning of engineering design. *Computers & Education*, *143*, 103669.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational psychologist*, *25*(1), 3–17.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In *Handbook of self-regulation* (pp. 13–39). Elsevier.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, *41*(2), 64–70.

CHAPTER 7

ARTICLE 4

Changes in students' Motivation and (Meta)cognitive Learning Strategy use: A Latent Transition Analysis using Autonomy support and Individual interest as covariates.

Kwarikunda, D., Schiefele, U., Hunt, T., Muwonge, C. M., & Ssenyonga, J. Changes in students' motivation and (Meta) cognitive learning strategy use: A latent transition analysis using autonomy support and individual interest as covariates. *Manuscript in preparation for journal submission* .

Abstract

Vast amount of education researchers have recommended for a need to track changes in students' motivation and (Meta) cognitive learning strategy use during STEM learning, if .effective and target-specific pedagogical interventions are to address the continued poor achievement in these subjects. Whilst drawing on the self-determination theory, the present study examined the changes in secondary school students' physics motivation and (Meta) cognitive learning strategies use during physics learning. Two waves of data were collected from initially 954 9^{th} students through to their 10^{th} grade. A three-step approach to Latent transition analysis was used. Generally, students' motivation decreased from 9^{th} to 11^{th} grade. Qualitative students' motivation profiles indicated strong with-in person stability whilst the quantitative profiles were relatively less stable. Mostly, students moved from the high quantity motivation profile to the extrinsically motivated profiles. On the other hand, the (Meta)cognitive learning strategies use profiles were moderately stable; with higher with-in person stability in the deep-level learner profile. None of the struggling users and surface-level learners transitioned into the deep-level learners' profile. Additionally, students who perceived increased support for autonomy from their teachers had higher membership likelihood into the competent users' profiles whilst those with an increase in individual interest score had higher membership likelihood into the deep-level learner profile. Practical implications of the study findings are further discussed in the paper.

Key words: Motivation, Learning strategies, Latent transition analysis, Latent profiles, Physics learning, Autonomy support, interest

7.1 Introduction

For the past several decades, there has been an increasing amount of variable centered research on learners' motivation and self-regulation in STEM subjects (e.g., Green et al., 2007; Kwarikunda et al., 2020; Lazarides et al., 2019; Muwonge et al., 2020; Potvin & Hasni, 2014). In these researches, various variable-centered associations of motivation with students' outcomes such as achievement (e.g., Chow and Yong, 2013), achievement emotions (e.g., Ekatushabe, Nsanganwimana, et al., 2021), beliefs and choices (e.g., Simpkins et al., 2006), cognitive learning strategy use (Ekatushabe, Nsanganwimana, et al., 2021; Kwarikunda et al., 2021; Pintrich, 2004) among others have been examined. These studies indicate that motivation is positively associated with achievement, positive achievement emotions and (Meta)cognitive learning. When learners believe they have high abilities to succeed in their studies, are autonomous to control their learning process, and exhibit high intrinsic motivation to extrinsic motivation ratios are more likely to employ a variety of deep-level learning strategies to reach their learning goals and thus are more likely to achieve highly than their counterparts (Muwonge et al., 2020; Pintrich, 2004 ; Vansteenkiste et al., 2009). Some of the existing studies have further taken a person-centered approach (Chittum and Jones, 2017 ; Corpus and Wormington, 2014; Hayenga and Corpus, 2010; Lazarides et al., 2016) to complement the existing variable centered approaches by uncovering the various combinations of motivation variables with in the latent subgroups of learners in a sample. Although these researches have generated new insights into the complex nature, associations, and implications of such complex motivation and self-regulation profile during STEM learning, due to their cross-sectional design there have been divergent conclusion and stipulations on the possible changes that could occur in students' science motivation with time.

Given that motivation has been proven to be malleable in nature and thus can change over time (Bouffard et al., 2003), one of the most recommended-for-further-research areas in motivation and (Meta)cognitive learning strategy use research has been the need for longitudinal studies, preferably using person-centered approach (PCA) to examine the probable changes that could occur in students' motivation and cognitive learning strategy use over time. Prior cross-sectional researches indicate that students have varying levels of motivation for science learning at different educational levels, with elementary students being more motivated to learn science (Hayenga & Corpus, 2010). Whilst comparing changes in students' motivation in their middle school and early secondary school, Wigfield and Eccles, 2000 states that overall negative change in academic motivation begins in early adolescence. Also, it is during this time that most young adolescents have to deal with the increasing academic demands in secondary school that usually require students to be highly autonomous, highly motivated, willing to work harder whilst regulating their own learning process (Eccles & Wigfield, 2002). If the students are to keep up with the competitive outcome-oriented stance common in secondary school (Ratelle et al., 2007), supporting their motivation development is key. Otherwise, a negative change in students' motivation can be persistent through the education levels post adolescence if not addressed earlier (Corpus & Wormington, 2014; Wigfield & Eccles, 2000). Nevertheless, Roeser and Midgley (1997) notes that not all students encounter these negative shifts in their motivation and self-regulation.

Contrary to Wigfield and Eccles (2002), Xie et al. (2022) argue that the changes in motivation are rather more complex than just an increase or decrease, especially when motivation is considered as a multi faceted construct in motivational research. A change in mean of one of the motivational constructs could mean that there are many within person changes that occur in a sample. Although Variable-Centered Analyses (VCA) can detect general (mean) changes in motivation variables of the student sample, these approaches cannot be used to examine the complex changes that occur in different subgroups (latent profiles) of students within the sample with increase in time. For example, if the sample mean of intrinsic motivation fluctuates, the increase or decrease might result into membership transition into or out of the intrinsic motivation profiles from or to other profiles, a pattern that is obscured by VCA. To uncover such complex changes, there is need to employ longitudinal person centered analyses. Understanding such changes in motivation patterns can better inform STEM teachers' pedagogy to support the development of motivation.

Motivation has a predictive influence on the quality, scope and results of learning activities (Muwonge et al., 2020;Xie et al., 2022). This could imply that if student's motivation is changing as they advance from one grade to another, we expect that their cognitive learning strategy usage also changes quantitatively and qualitatively, given that motivation influences cognitive learning strategy use during STEM learning (Ekatushabe, Nsanganwimana, et al., 2021; Kwarikunda et al., 2021; Schiefele, 1999). Students with low motivation tend to use more of the surface level learning strategies (Schiefele, 1999), are usually less autonomous and disorganized, are less interested, experience more difficulties in establishing and maintaining a structured approach to studying, have difficulty managing learning resources and thus will have reduced levels of achievement as compared to their counterparts with high motivation (Gillet et al., 2017; Kwarikunda et al., 2020). Thus, we can anticipate that a change in students' motivation can also influence changes in their cognitive learning strategy repertoire, which in turn could affect their science achievement.

Prior cross-sectional researches indicate that as students advance from one class to another, they tend to rely on rehearsal and organisation strategies as their intrinsic motivation levels reduce (Kwarikunda et al., 2020; Zhao & Qin, 2021). Such a change in class mean of cognitive learning strategy use could imply a shift in profile membership. However, to the best of our knowledge, there is no existing longitudinal person-centered research that examines changes in high school students' cognitive strategy use during Physics learning, and thus it is unclear of the likely changes that occur in secondary school students' cognitive learning strategy use with time. Of interest is the likely membership shift into a profile that is characterised with strategies that promote deep-level learning. As Schiefele, 1999 stated, the use of deep-level learning strategies usually foster lifelong learning.

From the existent literature, the changes in students' motivation and (Meta) cognitive learning strategy use vary within different contexts such as specific science subject (e.g. Green et al., 2007), social economic standard of the country in context (see Hunt et al., 2021), students class grade (Eccles et al., 1998) among others. To date, majority of the existing studies in literature are cross-sectional in nature, were conducted in developed countries, mostly used university or elementary students and were conducted in other subjects, rather than secondary school physics students from a developing country. Thus, there exists a knowledge gap about the possible longitudinal changes in secondary school physics students' motivation and (Meta) cognitive learning strategy use. To this regard, we designed a longitudinal study that uses Person Centered Approach (PCA) in which students' motivation and (Meta) cognitive learning strategies use were tracked across 18 months. Specifically, the present study extends literature on secondary school students' motivation and (Meta) cognitive learning strategy use during physics learning by using a longitudinal design to report i) within-person profile and within sample profile stability ii) while using a Latent Profile Analyses rather than sub optimal cluster analysis to determine the profiles upon which we relied to form the Latent Transition Analysis models. Cluster analyses were not used since they are highly criticized (see Meyer & Martin, 2016). Results from such a longitudinal track of these changes can be relied on to inform practical decisions on science pedagogy such as generating strategies that support the development of students' motivation and (Meta) cognitive learning strategy use which would result into a shift to increasing autonomous motivation and use of adaptive strategies that fostering lifelong science learning.

7.2 Literature

Within the self-determination theory framework (Deci & Ryan, 2008; Ryan & Deci, 2017) students can be motivated for several reasons, ranging from engagement in an activity for the pleasure and satisfaction it affords (intrinsic motivation), to participating in a task while mainly being driven by the externally driven forces e.g., rewards (extrinsic / controlled motivation), and a motivation; the lack of intentions toward a target behaviour. According to the SDT framework, these forms of behavioural regulations are not mutually exclusive, but rather different forms of motivation co-exist within individuals (Gillet et al., 2017). For instance, a student A can be highly intrinsically motivated but moderately extrinsically motivated. Another student B in the same class can be lowly intrinsically motivated but highly extrinsically motivated. There could be other students with various combinations of intrinsic-motivation self-efficacy and extrinsic motivation. Thus, a continuum of relative autonomy ranging from purely intrinsic motivation on one pole to a motivation on another pole exists (Deci & Ryan, 2000). More so, students could have combinations of motivation that vary in motivation quantity i.e., low motivation, moderate motivation; highly motivated; without specific distinctions in the quality of motivation.

To unveil such groups of concealed students within a sample, one has to employ PCA rather VCA (Collins & Lanza, 2010; Wang & Wang, 2012). To this regard several Person-Centered Approach (PCA) studies have been conducted with in the STD framework (e.g., Hayenga & Corpus, 2010; Kwarikunda et al., 2021; Liu et al., 2014; Muwonge et al., 2017; Vansteenkiste et al., 2009) to unveil the various subgroups of students within different contexts. Results indicate that indeed various combinations of motivation forms on the STD continuum exist differing significantly in quality, forming various motivation profiles of students (subgroups). On contrary to the SDT, these studies reveal existence of different profiles of students characterized with varying quantities of motivation, i.e., high levels of motivation, low levels of motivation, and moderate levels of motivation. Despite some variations in the nature and naming of the profiles due to the difference in motivation variables used, a similar SDT qualitative profile characterized with either i) high intrinsic-moderate extrinsic motivation, ii) high extrinsic- low intrinsic motivation, and or iii) low intrinsic-high self-beliefs-high extrinsic or equivalent was obtained in the above studies. Further on validating these motivational profiles whilst using various predictive and educational outcome variables, results confirm the existence of distinct subgroups of students based on their motivation. For instance, autonomous forms of students' motivation tend to significantly predict positive outcomes than controlled (extrinsic) motivation (e.g., Gillet et al., 2017; Guay et al., 2008; Hayenga & Corpus, 2010). When quantity profiles were obtained, high quantity motivation profiles tend to predict positive learner outcomes than low quantity motivation profiles (e.g., Hayenga & Corpus, 2010; Kwarikunda et al., 2021; Muwonge et al., 2020) .

However, most studies to date have not made an attempt to address the important issue of addressing the likely changes in students' motivation and (Meta) cognitive learning strategy use across time. The few existent studies (e.g., Corpus et al., 2009; Vallerand, 1997) have either used Variable-Centered Approaches (VCA) or hierarchy models to show fluctuations in students' motivation over time, the extent and nature of the fluctuations in these studies indicate conflicting results. For instance Corpus et al. (2009) documented a significant decline in both intrinsic and extrinsic motivation over a course of one year. Eccles et al. (1998) and Lepper et al. (2005) provide robust evidence of age-related declines in only intrinsic motivation which might suggest instability in profiles with high levels of intrinsic motivation. On the other hand, Hayenga and Corpus (2010) reported a shift towards increase in extrinsic motivation over time in middle school students. In terms of students self-beliefs, researchers provide evidence that self-efficacy is less stable among younger students than their older counterparts in upper secondary schools at least for mathematics (Davis-Kean et al., 2008; Talsma et al., 2018) and that this change in their self-efficacy is positive over time (e.g., Schöber et al., 2018) . Additionally, a review of the scant literature in (Meta) cognitive learning strategy use indicates that as students advance from one education level to another, as the learning tasks get complex, students tend to use more of the elaboration and rehearsal learning strategies (Muwonge et al., 2017). Although these studies indicate the mean change in students' motivation, they do not report within-person changes in the level and direction of the combinations of students' motivation simultaneously. To unveil within-person and within-sample changes simultaneously, one has to use PCA. Studying these changes could help to clarify the inconsistencies in the empirical research findings and enrich researchers' understanding of changes in secondary school students' motivation especially during Physics learning. Moreover, such a study could help identify groups of Physics students who may be more vulnerable than others to decreasing motivation and maladaptive learning strategy use over time.

Although there are scant longitudinal PCA studies in Science motivation and the use of (Meta) cognitive learning strategies, a review of such studies provides a glimpse of the relatable and expected changes that could be unveiled in the present study. When (Gillet et al., 2017) examined the extent to which University students' motivation profiles would remain stable over the course of two months, they report that unlike controlled motivation, quantity profiles (like moderately unmotivated and moderately autonomous) were less stable over time. This implies that profiles with combinations of autonomous and controlled motivation are least stable with time. When transitions occurred for the autonomous profile, members moved into other relatively autonomous profile (strongly motivated 7.6% and moderately autonomous 10.6%).

On the contrary, whilst using a sample of 343 middle-school students, Hayenga and Corpus (2010) examined the shifts in four motivational profiles over the course of a school year. Their results indicate that across two time points, membership movement tended to be away from the good quality and high quantity clusters and towards the poor quality and low quantity clusters. Whilst using a younger sample, Corpus and Wormington (2014) examined patterns of stability and change in profile membership in elementary students and noted that although the 3 clusters were moderately stable. Majority of the students in the high-quantity shifted into the primary intrinsic and primarily extrinsic profile over the course of the year. The primarily intrinsic cluster was most stable cluster.

Similarly, when Oga-Baldwin and Fryer (2018) examined motivation profile stability in Japanese elementary schools, they also found that the good-quality profile was the most stable (83% – 92%), followed by the high-quantity (62% – 89%) and poor-quality profiles (12% – 46%). When profile members transitioned, greater movement was towards profiles with more autonomous motivation. Precisely members were moving from poor-quality to high-quantity profiles and from high-quantity to good-quality profiles. In line with Corpus and Wormington (2014), they concluded that probably when elementary students transitioned, membership was more likely into autonomously motivated profiles.

To differ from other studies, Xie et al. (2022) used a high school sample which is similar to the present study in some way, only that they examined general motivation whilst the present study examines Physics motivation. Never the less, they found that the balanced motivation and moderately motivated profiles were more stable from year one to year two. More so, high school students were more likely to transition into more adaptive to less adaptive motivation profiles.

Clearly from the above studies, the stability and volatility of the motivational profiles as well as the shifting patterns among the motivation profiles are inconsistent. Probably these results could be attributed to the methodological (mostly use cluster analysis and difference in motivation constructs used) and contextual differences. Also, as noted in the above literature, to the best of our knowledge no longitudinal PCA study has examined possible changes in students metacognitive learning strategy use in secondary schools. The existing longitudinal study has been conducted in University students (Hong et al., 2020). Since no similar existing study has been conducted using a lower secondary school sample, in physics as a specific learning subject, and in a developing country, it is unclear to what extent results from the existing studies can be generalized to the current study sample. Thus, we designed the present study to fill the above knowledge gap.

Perceived autonomy support and interest as predictors of (Meta)cognitive learning strategy use (Meta)cognitive learning strategies have been found to be important for science achievement and continued deep-level learning (Schiefele, 1999; Zhao & Qin, 2021). To improve learning, previous research (e.g., Muwonge et al., 2020) has highlighted the importance of developing students' (Meta)cognitive learning skills, for lifelong learning. Much of this research in the SDT framework has linked the development of (Meta)cognitive learning strategies to factors such as students' motivation, interest, and autonomy support among others (Ryan & Deci, 2017). For instance, previous studies indicate that when learning takes place in an autonomous environment, students are more interested in the learning contents, actively participate in classroom activities, are encouraged to think deeply about the learning content and voluntarily have control of the learning process and choice of learning strategy to us (Ryan & Deci, 2004). On the other hand, lack of autonomy support by teachers hinders development of students' psychological engagement and voluntary learning behaviour (Stefanou et al., 2004). Because the learning environment seems compulsive without autonomy, students' will for voluntary interest and internal incentive mechanisms are dampened (Ekatushabe, Kwarikunda, et al., 2021; Reeve et al., 2004; Ryan & Deci, 2004) and consequently, learners become less intrinsically driven to learn, less interested in the learning content and will adopt shallow learning strategies resulting in poor academic performance (Filippello et al., 2020).

Further previous studies indicate that perception of varying degrees of teachers' autonomy support can have an impact on students' motivational constructs and students' learning process (Reeve et al., 2004; Zhang et al., 2018). If given choice, learners are willing to engage in activities they are more interested in, whilst using deep level (Zhao & Qin, 2021). Due to scanty research on the predictive effect of perceived autonomy support and individual interest on likely (Meta)cognitive learning strategy use especially in Physics, we designed the present study to fill the knowledge gap. To deviate from the existing researchers, the present study takes a PCA approach to unveil the possible predictive effects of perceived teacher autonomy support and individual interest on membership likelihood in different latent groups of learners.

7.2.1 Present study

The present study is an extension of two studies (Kwarikunda et al., 2022; Kwarikunda et al., 2021). Although, in these two studies we made an attempt to examine students motivation and (Meta)cognitive learning strategy use during Physics learning using P.C.A, these studies were limited by their cross sectional nature. Thus we could not examine the complex within-sample and within-person changes that could occur in students' motivation and (Meta)cognitive learning strategy use over time. More so, recent studies have increasingly pointed out that profiles of motivation and consequently (Meta)cognitive learning strategy use and how they change over time are likely dependent on students' developmental levels (Linnenbrink-Garcia et al., 2018). Further, there is scant literature on the predictive effect of gender, age, interest and perceived autonomy support on the likelihood of membership into the (Meta)cognitive learning strategy profiles.

To this regard, a longitudinal study was designed to address the above limitation. Given that the present study is an extension of the two studies, the same sample was used. We expected that the same number of motivation and (Meta)cognitive learning strategy use latent profiles would be obtained at different time points. We hypothesized that the profiles nature (except profile size) would be the same as in Kwarikunda et al. (2021) and Kwarikunda et al. (2022) for the motivation and (Meta)cognitive learning strategy use variables respectively. Further, based on previous V.C.A researches, we hypothesized that the quality profiles were more stable than the quantity profile across time and thus, that there would be an increase in size of the quality profiles with time. Furthermore, we examined the predictive effects of gender, age, individual interest, and perceived autonomy support on the likelihood of memberships into the (Meta)cognitive earning strategy use profiles. We expect that an increase in the levels of perceived autonomy support and individual interest increases membership likelihood into deep-level learning profile.

7.3 Methods

7.3.1 Participants

Initially, 952 9^{th} grade students (50.3% females) from 8 secondary schools in central Uganda were recruited for the longitudinal study. However, 534 students participate in second phase of the study. 28 of these students participated in the second phase of the study but did not participate in the first phase of the study and thus were eliminated for data analysis, implying that data for 506 students was used for analyses. Most of the students were 15 years old (Mean = 15.26, SD = 1.36) at the start of the study.

7.3.2 Procedure

Students completed surveys at two different points in time (from their 9^{th} grade. At each time point, the surveys were administered to the students during their regular physics classes by the research team. Before administering the surveys, students were briefed about the aim and purpose of the study, as well as other ethical issues like confidentiality and data security. Each student was given a code known to only members of the research team that corresponded with the student name on the class list. This way, the students were each given a questionnaire with the code so that they could not write their names and those of their school on the questionnaire for purposes of anonymity. The study was approved by Mbarara University of Science and

Technology and Universität Potsdam Research Ethics Commissions.

7.3.3 Measures

Data was collected using a self- reported questionnaire. The questionnaire consisted of five sections. The first section elicited students' socio-demographic characteristics e.g. gender, age, residence status, and highest education level of their parents. Gender was recorded as a binary variable. The other sections are briefly discussed below.

Motivation

In the second section we assessed Students' motivation for Physics learning using an adapted 24-item Physics version of modified Science Motivation Questionnaire II (Kwarikunda et al., 2020 ; original version by Glynn et al., 2011). We replaced words such as "Science" and "grade A" with "Physics" and "between 75% and 100%" respectively to fit the instrument into the context of the study. All the five subscales: intrinsic motivation, grade motivation, career motivation, self-efficacy, and self-determination were assessed. The items were answered on a 5-point Likert scale ranging from 1 (never) to 5 (always). Example of the items include Previous research has provided evidence of SMQ-II reliability and validity (e.g. Kwarikunda et al., 2020) for this sample. The internal consistencies as indexed by Cronbach's alpha were satisfactory (alpha range 0.67 - 0.79). Confirmatory Factor Analysis (CFA) indicated that a 5-factor model solution fitted with our data.

7.3.4 *Individual Interest*

In the third section, students' individual interest in Physics learning was assessed using the Individual Interest Questionnaire (IIQ; Rotgans, 2015). The scale consisted of 7 items e.g., "I am very interested in Physics", and "that were rated on a 5-point Likert scale, ranging from 1 (not true at all) to 5 (very true for me). The reliability coefficient of the IIQ was satisfactory (α = 0.78 - 0.81).

7.3.5 *(Meta)cognitive Learning Strategies*

Five different aspects of cognitive and metacognitive learning strategies (i.e., rehearsal, elaboration, critical thinking, organization and metacognitive self-regulation) were assessed using cognitive and metacognitive learning strategies section of the Motivated Strategies Learning Questionnaire (MSLQ; Pintrich et al., 1991). All items were answered on a 7-point Likert scale ranging from 7 (very true of me) to 1 (not at all true for me). An example of the items that assessed rehearsal use is “When studying for Physics, I read my class notes over and over again”. Reliability coefficients at different time points were satisfactory (α = 0.78 - 0.81).

Perceived Autonomy Support

The last section of the questionnaire assessed students’ perceived teacher’s autonomy support. This section comprised of 15 items that we adapted from Williams and Deci’s (1996) Learning Climate Questionnaire (LCQ; α = 0.91). Sample items included “I feel that my physics teacher provides me choices and options” and “my physics teacher shows confidence in my ability to do well in physics tests”. The items were scored on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Following a confirmatory factor analysis using Data at Time 1, one item “I feel able to share my feelings with my physics teacher” had a factor loading less than 0.40 and thus this item was consequently excluded. Reliability coefficients were satisfactory.

7.3.6 Analyses

Preliminary Analyses

Initially, data were first screened for missing values, outlier, normality, sampling adequacy and sphericity to ascertain their suitability for use in the main analyses. This was done on each of the cross sectional data waves separately. The missing values were handled by the full-information-maximum-likelihood method, since this method is more efficient as compared to other methods (Wang & Wang, 2012). The Shapiro-Wilk test was used as a test for normality. We obtained a non-significant values ($p\mathrm{T}_1$ = 0.74, $p\mathrm{T}_2$ = 0.77) which indicate that the distribution of our data at the different data collection time points was normal. On conducting a Kaiser-Meyer-Olkin Measure of Sampling Adequacy, and our data passed this test (KMOT_1 = 0.92, KMOT_2 = 0.94). Further, Bartlett's test of sphericity indicated that the correlation matrix of items at T_1 was of adequate quality (χ^2 = 2876.98, $p < 0.05$). Furthermore, we conducted preliminary factor analyses using CFA to verify the fitness of the factors with our data. We followed Hu and Bentler (1999) model fit criteria: Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) $\geq$ 0.90, Standardized Root Mean Square Residual (SRMR) $\leq$ 0.08, and Root Mean Square Error of Approximation (RMSEA) $\leq$ 0.06. Correlations were also done to assess relatedness of the study variables (see table).

Latent profile Transition Analysis

In the first step, a series of Latent Profile Analysis (LPA) models were estimated separately at each time point in order to ensure that the same number of profiles would be extracted at each time point (Gillet et al., 2017; Wang & Wang, 2012) . Additionally, we estimated the number of motivation and cognitive and metacognitive learning strategy usage profiles separately for each time point. For each time point, latent profile models with an increasing number of ***k*** latent profiles ranging from 1-8 were examined. To determine the optimum latent profile model, multiple criteria including: theoretical conformity, substantive meaningfulness of the profiles, and statistical adequacy (Gillet et al., 2017; B. Muthén, 2003) were used. Statistical indices such as Akaike's Information Criterion (AIC; Akaike, 1974), Bayesian Information Criterion (BIC; Schwarz, 1978), and sample size Adjusted BIC (ABIC; Sclove, 1987) were used. A model that produces smaller values of AIC, BIC and ABIC has a better fit (Wang & Wang, 2012).

Additionally, likelihood ratio statistic tests such as Lo-Mendell-Rubin likelihood ratio test (LMR), adhoc adjusted LMR, and Bootstrap Likelihood Ratio Test (BLRT; McCutcheon, 1987) that assess improvement in neighbouring class models by comparing normal mixture distribution of the ***k*** class against an alternative ***k-1*** class were also used. A probability value $<$ 0.05 implies that there is statistically significant improvement in the ***k*** profile model than in the ***k-1*** profile model. Thus, the ***k*** profile model which is of better fit to the data is accepted, whilst the ***k-1*** profile model is rejected (Wang & Wang, 2012). Basing on results from simulation studies, BLRT performs better in estimating the best model fits as compared to other likelihood tests (Asparouhov & Muthen, 2007); Berlin, William & Para, 2013). Thus, we prioritized BLRT results before we could use other likelihood ratio statistics. Entropy-based criterion which assess the quality or adequacy of latent profile membership were also used. However, entropy was not used to determine the optimum number of profiles (see Lubke & Muthén, 2007). A normalized entropy value greater than 0.8, indicates that the latent profiles are highly discriminating. As recommended by Wang and Wang (2012) , a further examination of the posterior classification probabilities and profile size distribution was done. A model, whose profiles' posterior classification probability values are greater than 0.85, indicates adequate membership allocation. A profile with size of $< 5\%$ is problematic, and it is recommended to reject the model with such a profile size. In regard to Vermunt (2010) recommendation, we also examined the profiles interpretability in respect to the theory underlying the study.

Upon establishing the optimum number of profiles t each time point, the three retained LPA model solutions were integrated into a single longitudinal LPA model. This allows for systematic longitudinal tests of profile similarity (Morin & Wang, 2016). We followed a manual auxiliary 3-step approach to LTA as recommended by Asparouhov and Muthén (2014). The 3-step approach ensures that the measurement of the latent profiles variable is not affected by inclusion of covariates (Nylund-Gibson et al., 2014). In the first step, the longitudinal LPA was estimated from a model of configurational similarity (Collins & Lanza, 2010; Wang & Wang, 2012). In the second step, structural similarity of the profiles was verified by including equality constraints across time points on the means of the profile indicators. This was done to test whether the profiles retained the same shape over time (Gillet et al., 2017). Then, the tests of the dispersion similarity of the profiles were done to verify whether the within-profile variability remains stable across the time points. Lastly, the distributional similarity of the profiles was tested. Fit of the models was compared using the aforementioned statistical indices. The smaller the values of AIC, BIC and ABIC, the better the model fits the data (Morin & Wang, 2016; Wang & Wang, 2012).

Predictors of Cognitive and Metacognitive Learning Strategy Use profile membership

Using the similar 3-step approach sequence, predictive variables were included in the LTA. Multinomial logistic regressions were conducted to test for the predictive relationship of age gender, interest, and perceived autonomy support on the cognitive and metacognitive learning strategy profiles at the three time points. Initially, the relations between profile membership and predictors were freely estimated across time points. Before testing for predictive similarity, predictions were also freely estimated across time but not profiles (recommended by Asparouhov & Muthén, 2014; Gillet et al., 2017). All model analyses were estimated in Mplus 8 (L. K. Muthén & Muthen, 2017).

7.4 Results

7.4.1 Preliminary Results

Results in Table 7.1 indicate CFA fit indices of the measurement model to data across times. Fit indices indicate that the measurement model fit data at different time points. In Table 7.2 are the various reliability coefficients and descriptive means of the study variables. When graphically represented, figure 7.1 indicates that unlike perceived teacher autonomy support, individual interest was relatively stable across different time point. In Figure 7.2, physics students' motivation increased between 8^{th} and 9^{th} grade and decreased in 10^{th} grade. Specifically at time 3, noticeable decrease occurred in their intrinsic motivation, self-efficacy and carrier motivation whilst the students' grade motivation was the highest. In Figure 7.3, students between 8^{th} and 9^{th} grade used relatively similar cognitive and metacognitive learning strategies. However, between 9^{th} and 10^{th} grade, the usage of rehearsal increased while that of organisation and critical thinking learning strategies decreased, with the highest decrease being registered in usage of critical thinking.

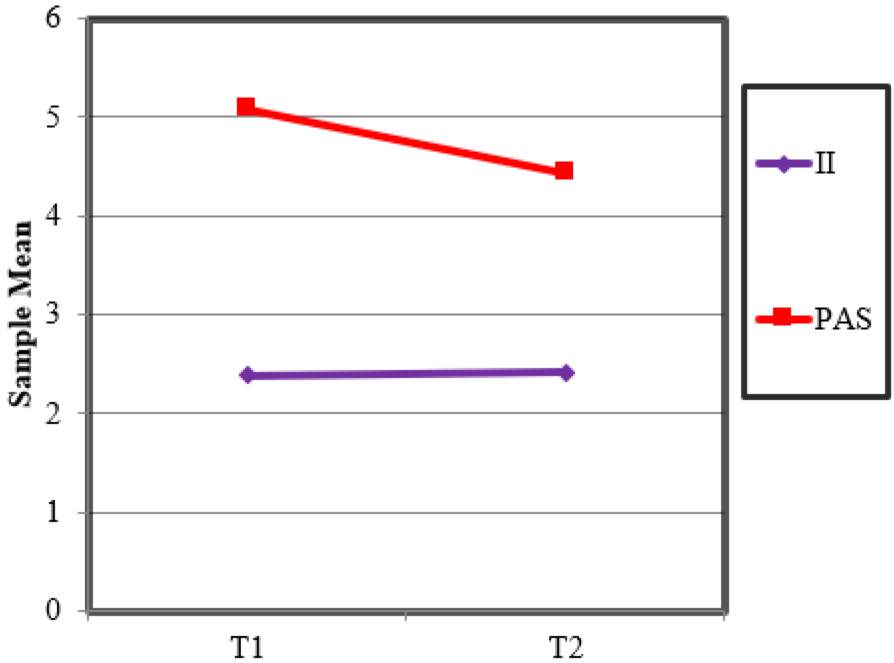
Table 7.1

Fit Indices of the various sections of the Questionnaire at T_1

Instrument section	Fit indices				
	χ^2/ df	CFI	TLI	SRMR	RMSEA
Motivation	1.29	0.93	0.92	0.06	0.04
(Meta)cognitive learning strategies	1.53	0.93	0.91	0.06	0.04
Individual interest	1.26	0.94	0.93	0.07	0.05
Perceived Autonomy support	1.38	0.92	0.91	0.06	0.04

Figure 7.1

A Graph showing Changes in students' Perceived Autonomy Support and Interest over Time.



Note. II, Individual interest; PAS, Perceived teacher autonomy support

Table 7.2

Descriptive Statistics and Reliability Coefficient of different Sub-scales at different Times

Time point	variable	α	Overall sample	Boys	Girls
			M (SD)	M (SD)	M (SD)
T_1: 9th grade	Perceived autonomy support	0.86	5.08(1.18)	5.12(1.03)	5.05(1.18)
	Intrinsic motivation	0.7	2.68(0.84)	2.69(0.92)	2.61(0.79)
	Self-efficacy	0.78	2.94(0.83)	3.01(1.02)	2.96(0.81)
	Self determination	0.69	2.72(0.76)	2.71(0.71)	2.74(0.85)
	Grade motivation	0.72	3.13(0.73)	3.19(0.82)	3.11(0.69)
	Career motivation	0.68	2.94(0.90)	2.97(0.99)	2.91(1.01)
	rehearsal	0.83	5.08(1.29)	5.09(1.32)	5.04(1.27)
	organisation	0.82	5.20(1.13)	5.15(1.09)	5.21(1.08)
	elaboration	0.87	5.23(1.25)	**5.09(1.34)**	**5.36(1.16)****
	Critical thinking	0.79	4.74(1.29)	4.79(1.30)	4.67(1.09)
	Meta-cognition	0.89	5.24(1.13)	5.21(1.67)	5.25(1.54)
	interest	0.75	2.39(0.80)	2.43(0.81)	2.34(0.99)
T_2: 11th grade	Perceived autonomy support	0.85	4.53(1.08)	4.60(0.98)	4.51(1.05)
	Intrinsic motivation	0.7	2.36(0.92)	2.39(1.03)	2.21(1.13)
	Self-efficacy	0.79	2.57(0.85)	2.64(0.87)	2.53(1.02)
	Self determination	0.7	2.84(0.91)	**2.93(1.05)**	**2.46(0.97)****
	Grade motivation	0.72	3.48(0.75)	3.53(1.03)	3.37(1.21)
	Career motivation	0.69	2.53(0.84)	**2.64(1.06)**	**2.32(0.91)****
	rehearsal	0.82	5.63(1.32)	**5.56(1.42)**	**5.74(1.08)****
	organisation	0.82	5.03(1.24)	4.97(1.68)	5.07(1.41)
	elaboration	0.87	5.13(1.21)	**5.19(1.22)****	**4.82(1.31)****
	Critical thinking	0.8	4.13(0.99)	4.20(1.09)	4.04(0.99)
	Meta-cognition	0.89	5.22(1.03)	5.31(1.04)	5.18(0.98)
	interest	0.76	2.35(1.06)	2.39(0.99)	2.32(1.03)

$^{**}p < 0.05$

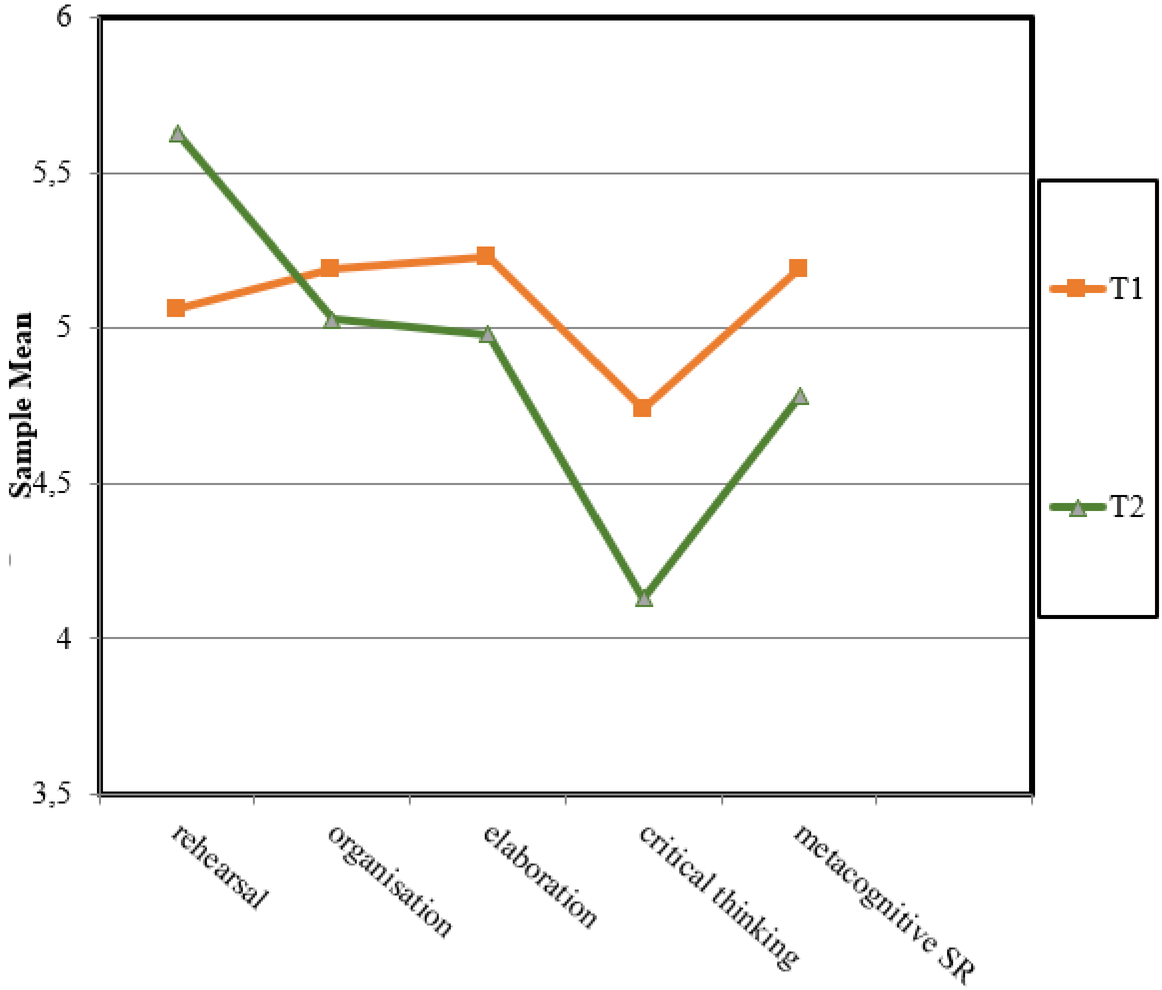
Figure 7.2

A Graph showing Changes in students' Motivation over Time.

Note. IM, Intrinsic motivation; SE, Self-efficacy; SD, Self-determination; CM, Career motivation; GM, Grade motivation

Figure 7.3

A Graph showing Changes in students' Cognitive and Metacognitive Learning Strategy Use over Time.



Note. Metacognitive SR, Metacognitive self-regulation.

7.4.2 Latent Profile Analyses

Fit indices of the various LPA models at each time point are reported in Table 7.3 and Table 7.4. On examining the results, generally, BLRT improved with increase in number of profiles. Since information criteria indices were decreasing with increasing number of profiles, we also examined the graphical elbow point to complements BLRT during fit model selection. These plots flatten out between 4 and 7- Motivational profile and between the 3 and 5- cognitive and metacognitive learning strategy usage profiles models. Thus a 6- motivational profile solution and a 4- cognitive and metacognitive learning strategy usage profile solutions were retained at each time point. Table 7.6 indicates the fit indices from the final time-specific LPAs and all longitudinal models. In the present study, profiles were identified as similarly in Kwarikunda et al. (2021) and Kwarikunda et al. (2022).

Table 7.3

Fit Indices at each Time point using Motivational variables as Profile Indicators

Time point	Index	Model						
		1-profile	2-profile	3-profile	4-profile	5-profile	**6-profile**	7-profile
	BLRT	-	<0.001	<0.001	<0.001	0.03	**0.03**	0.51
T_1	nf	10	16	22	28	34	**40**	46
	LL	-2256.57	-1911.54	-1829.85	-181	-1789.79	**-1678.34**	-1601.52
	AIC	4533.14	3855.07	3702	3677.7	3647.58	**3597.35**	3587.45
	BIC	4572.39	3917.86	3788.33	3787.58	3781	**3652.32**	3765.75
	ABIC	4540.69	3867.1	3718.53	3698.75	3673.13	**3646.23**	3534.98
	Entropy	-	0.857	0.846	0.819	0.831	**0.91**	0.752
	BLRT	-	<0.001	<0.001	0.02	0.04	**0.04**	0.19
T_2	nf	10	16	22	28	34	**40**	46
	LL	-2133.43	-1721.45	1814.21	-1781.72	-1768.92	**-1607.29**	-1582.07
	AIC	4241.14	3881.01	3692.4	3602.91	3592..43	**3486.14**	3561.79
	BIC	4421.81	3801.51	3606.73	3698.18	3617.87	**3594.43**	3649.09
	ABIC	4418.08	3592.84	3518.93	3621.53	3589.94	**3508.19**	3523.78
	Entropy	-	0.841	0.837	0.801	**0.812**	**0.892**	0.791
	BLRT	-	<0.001	<0.001	<0.001	<0.001	**0.03**	0.21

Note. nf, free parameters; LL, model loglikelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC; BLRT, bootstrap likelihood ration Test. Bold indices are for the selected model at each time point.

Table 7.4

Fit Indices at each Time point using Cognitive and Metacognitive Learning Strategies as Profile Indicators

Time point	Index	Model					
		1-profile	2-profile	3-profile	**4-profile**	5-profile	6-profile
T_2	nf	10	16	22	**28**	34	40
	LL	-3306.93	-3150.12	-3218.77	**-3161.81**	-3118.81	-2909.57
	AIC	6178.29	5882.09	5564.18	**5485.47**	5006.17	4909.19
	BIC	6209.03	5978.16	5639.02	**5724.98**	5179.93	5156.02
	ABIC	6148.83	5924.08	5597.19	**5661.74**	5071.22	4927.98
	Entropy	-	0.801	0.812	**0.839**	0.817	0.798
	BLRT	-	<0.001	<0.001	-	-	-
	<5% class size	-	0	0	**0**	1	1
T_3	nf	10	16	22	**28**	34	40
	LL	-3291.84	-3206.39	-2786.9	**-2686.18**	-2591.43	-2487.49
	AIC	6087.72	5919.86	58.62.93	**5797.54**	5644.43	5601.12
	BIC	6121.2	6002.78	5960.37	**5801.51**	5743.15	5668.09
	ABIC	6089.1	5844.81	5538.02	**5436.89**	5391.79	5103.48
	Entropy	-	0.803	0.819	**0.84**	0.821	0.761
	BLRT	-	<0.001	<0.001	**0.026**	0.04	0.5
	<5% class size	-	0	0	**0**	1	1

Note. nf, free parameters; LL, model loglikelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC; BLRT, bootstrap likelihood ration Test. Bold indices are for the selected model.

Table 7.5

Results from Latent Profile Analyses and Latent Transition Analyses using Motivational variables

Model	nf	LL	Scaling	AIC	BIC	ABIC	Entropy
Final latent profile analyses							
Time 1	40	-1678.34	1.63	3597.35	3652.32	3646.3	0.910
Time 2	40	-1607	1.73	3486.14	3594.43	3508.19	0.892
Longitudinal latent profile analyses							
Configural similarity	135	-2580.75	1.78	5710.86	5847.63	5754.13	0.894
Structural similarity	105	-3671.02	1.92	5989.57	6174.10	6018.17	0.902
Dispersion similarity	75	-3818.45	1.68	5841.02	5950.13	5873.07	0.893
Distribution similarity	70	-3106.34	1.91	5786.39	5799.02	5617.48	0.888
Latent transition analysis	45	-2151.14	0.94	1937.43	2005.92	1951.74	0.912

Note. nf, free parameters; LL, model log likelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC.

Table 7.6

Results from Latent Profile Analyses and Latent Transition Analyses using Cognitive and Metacognitive Learning Strategies use variables

Model	nf	LL	Scaling	AIC	BIC	ABIC	Entropy
Final latent profile analyses							
Time 1	28	-3161.81	1.42	5285.47	5724.78	5361.74	0.839
Time 2	28	-2686.18	1.43	5797.54	5661.74	5436.89	0.840
Longitudinal latent profile analyses							
Configural similarity	80	-4935.61	1.41	8501.29	8987.30	8770.96	0.829
Structural similarity	50	-5018.86	1.78	8654.65	8891.13	8804.61	0.813
Dispersion similarity	70	-5132.57	1.53	8572.22	8742.64	8701.83	0.808
Distribution similarity	65	-5150.14	1.72	8501.83	8609.24	8698.44	0.809
Latent transition analysis	25	-1398.86	0.7147	2034.33	2150.22	2096.77	0.803
Predictive similarity							
Profile-specific free relations with predictors	95	-2075.92	0.608	2975.24	3451.39	3314.34	0.832
Free relations with predictors	65	-2162.91	0.813	2753.43	3378.64	3281.57	0.824
Equal relations with predictors	40	-2218.64	0.851	2616.56	3304.97	3247.41	0.839

Note. nf, free parameters; LL, model log likelihood; AIC, Akaike's information criterion; BIC, Bayesian information criterion; ABIC, sample-size adjusted BIC.

Table 7.7

Motivation Profiles' Transition Probabilities for the Final Latent Transition Analysis

	Transition Probabilities to Time 2 Profiles					
	LQ	MQ	HQ	PI	GI	EM
Time 1						
LQ	0.725	0.011	0.000	0.000	0.091	0.061
MQ	0.082	0.592	0.098	0.007	0.010	0.051
HQ	0.126	0.014	0.497	0.010	0.313	0.237
PI	0.016	0.000	0.042	0.929	0.021	0.067
GI	0.101	0.034	0.049	0.000	0.739	0.101
EM	0.134	0.0178	0.025	0.019	0.19	0.556

Note. LQ, low quantity profile; MQ, Moderate quantity profile; HQ, High quantity profile; PI, Primarily intrinsically motivated learner profile; GI, grade introjected learner profile; EM, mostly extrinsically motivated learner profile

7.4.3 Latent Transition with-in the Motivational profiles:

Transition probabilities from the LTA are reported in Table 7.7. These results indicate that from time T_1 to T_2 membership into low quantity profile (stability of 72.5%), primary intrinsic profile (stability of 92.9%), and grade introjected profile (stability of 73.9%) is the most stable over time. On the contrary, membership into moderate quantity profile (stability of 59.2%), high quantity profile (stability of 49.7%), and extrinsically motivated profile (stability of 55.6%) is less stable over time, with high quality profile being the least stable. Thus profiles characterized based on quantity of motivation were generally less stable than those characterized by quality of motivation over time.

Transition were rare for participants initially corresponding to grade introjected and primary intrinsic profiles. When transitions occurred for the members in the quality profiles, they mainly involved other quality profiles rather than quantity profiles. For example, less members from the extrinsically motivated profile transitioned into low quantity profile (1.34%), moderate quantity profile (1.78%), and high quantity profile (2.5%) compared to those who transitioned grade introjected profile(12.3%). However, when transitions occurred for members in the quantity profiles, these transitions mainly involved quality profiles rather than quantity profiles. For example most members initially from the high quantity profile transitioned into grade introjected profile (31.3%) and extrinsically motivated profile (23.7%) rather than into the moderate quantity profile (0.00%) and (12.6%) low quantity profile.

Overall, most members transitioned into the grade introjected profile (12.3% from extrinsically motivated; 23.1% from primary intrinsic; 14.2% from high quantity; and 1% from moderate quantity) as compared to transitions into other profiles. On the contrary, less members transitioned from the low quantity profile into other profiles.

7.4.4 Latent Transition with-in the Learning Strategy use profiles

Transition probabilities from LTA are reported in Table 7.7. Results show that membership into deep-level learning profile (stability of 87.2%) is stable followed by surface-level learning profile (75.4%) and struggling user profile (72.1%) over time. On the contrary, membership into competent users' profile (57.3%) was least stable compared to other profiles over time. Specifically, most of the struggling users profile members transitioned into surface-level learning profile (21.6%). None of members from the surface-level learning profile and struggling users members transitioned into deep-level learning profile.

Most of the deep-level learner profile members transitioned into competent users' profile (10.1%) whilst the Competent users profile members transitioned mostly to the surface-level learner profile (25.9%) and the deep-level learning (13.1%). None of the members transitioned from struggling users profile and surface-level learners profile to deep-level learners profile.

Table 7.8

Cognitive and Metacognitive Learning Strategies Use profiles' Transition Probabilities for the Final Latent Transition Analysis

	Transition Probabilities to Time 2 Profiles			
	SU	CU	DL	SL
Time 1				
SU	0.721	0.083	0.000	0.216
CU	0.259	0.573	0.131	0.074
DL	0.071	0.101	0.872	0.061
SL	0.212	0.143	0.000	0.754

Note. SU: surface learners; CU: competent learners; DL: Deep-level learners; SL: Surface-level learners.

7.4.5 Predictors of Membership into the various (Meta)cognitive Learning Strategies use profiles

Interest, perceived teacher autonomy support, gender and age were added to the LTA model as covariates in step 3. The effects of the predictors were estimated across time points and time 2 profiles. Then the model in which the predictive variables were contracted and be equal time point. Fit indices (Table 7.8) support predictive similarity. Results from the multinomial logistic regression analyses indicate that women were 2.1 - 2.6 times more likely to be members of the competent users and surface-level learners' profiles than in the struggling users and deep-level learning profiles. Older students were 1.12 times more likely to be members of deep-level profile than competent profile as compared to younger peers.

In regard to interest and perceived teacher autonomy support, more extensive associations with the likelihood of membership in the various (Meta) cognitive learning strategy use profiles were noted. Precisely, higher levels of interest and perceived autonomy support predicted an increased likelihood membership into competent user and deep-level learning profiles and negative membership likelihood into the struggling profile.

Table 7.9

Results of Multinomial Logistics Regression of Age, Gender, Interest, and Perceived Autonomy Support on the Cognitive and Metacognitive Learning Strategies use Profiles

Predictor	Profile 1 vs Profile 2		Profile 1 vs Profile 3		Profile 1 vs Profile 4	
	Coeff(SE)	OR	Coeff(SE)	OR	Coeff(SE)	OR
Interest	-0.521(0.15)**	2.21	0.139(0.07)	1.67	-0.47(0.390)**	1.33
Percieved autonomy support	-0.472(0.08)**	1.57	0.281(1.03)	1.83	-0.231(0.09)**	1.16
Gender	0.390(0.510)	2.65	-0.316(0.130)**	2.03	0.412(0.170)**	2.30
Age	0.312(0.780)	1.15	0.546(0.390)	1.07	0.219(0.07)**	1.31
	Profile 2 vs Profile 3		Profile 2 vs Profile 4		Profile 3 vs Profile 4	
	Coeff(SE)	OR	Coeff(SE)	OR	Coeff(SE)	OR
Interest	0.713(0.100)**	1.09	-0.317(0.08)**	1.06	-0.427(0.130)**	1.52
Percieved autonomy support	0.269(0.410)**	1.14	0.486(0.200)**	1.57	-0.296(0.410)**	1.02
Gender	0.184(0.330)	1.18	0.218(0.370)	1.53	0.221(0.081)**	2.10
Age	0.069(0.210)	1.75	-0.153(0.140)**	1.12	0.219(0.920)	1.22

$**p < 0.05$

Note. The coefficients(Coeff) and odds ratio (OR) reflect the effects of the predictor on the likelihood of membership in the first listed profile relative to the second. Profile 1: Struggling users; 2: Competent users; 3: Surface-level learners; 4: deep-level learners. Gender was a binary variable 1: Male; 2: Female.

7.5 Discussion

The purpose of the present study was to examine within-person and within-sample stability in motivation and (Meta)cognitive learning strategy use profiles in physics secondary school students across a 2-year period, in response to prior motivation and (meta) cognitive learning strategy researchers' recommendations for a need for a longitudinal study to examine the changes in students' motivation and (Meta) cognitive learning strategy use over time. Contrary to the few existing longitudinal studies that used elementary (e.g., Corpus & Wormington, 2014; Oga-Baldwin & Fryer, 2018) and university students (e.g., Gillet et al., 2017), the present study was conducted using secondary school physics students. Although pedagogically different from mathematics, results from the current study could be insightful for both mathematics and physics education.

Since few longitudinal VCA studies exist, initially, we examined the sample means of the various motivation and (Meta) cognitive variables at different time points. Results from such an analysis provide an insight into the likely average changes that could have occurs in physics student's motivation and (Meta) cognitive learning strategy use with increase in grade. In the present study, there was a decrease in students physics learning motivation. Notably, was the decrease in students' intrinsic motivation, self-efficacy and career motivation with lowest means observed among girls. Likewise, the use of deep- level learning strategies decreased in 11^{th} grade whilst that of surface- level learning strategies increased in 11^{th} grade. Previous researches indicate that as students advance from on educational level to another, there is a possible likelihood of developing a learning strategy repertoire, which is significantly influenced by the learners level of motivation, autonomy, task difficulty, and previous achievement (Gillet et al., 2017; Kwarikunda et al., 2020; Zhao & Qin, 2021). Such changes in the sample mean of motivation and (Meta)cognitive learning strategy use imply that the combinations of the motivation and (Meta) cognitive learning strategy use of the individual students (with-in persons) are also changing. In this study, we uncovered the likely within-persons changes that occur in students' physics learning motivation and learning strategy use as they advance from grade to another.

By adapting a longitudinal design, the current study addresses the joint issues of within-person stability and with-in sample stability. To examine with-in sample stability, we conducted LPA rather than cluster analyses at each time point. Our results revealed that a set of profiles were fully replicated across measurement occasions. Specifically, the same numbers of profiles characterized by the motivational and (Meta) cognitive learning strategy configurations were obtained, revealing configured and structural similarity (Collins & Lanza, 2010; Gillet et al., 2017). Given that the sample was the same, the motivational profiles were identified as in Kwarikunda et al. (2021). Whilst the (Meta) cognitive learning strategy use profiles were also identified similarly as in Kwarikunda et al. (2022). The difference between the present study and the later study was in the class size. The present study profiles are bigger than those in the latter study. On analysis of the within profile stability, results show that the motivation and (Meta) cognitive learning strategies use profiles remain moderately to highly stable over time in.

Specifically, in line with Gillet et al. (2017), the low quantity profile (72.5%), primary intrinsic (92.9%), and grade introjected (75.9%) profiles were more stable than the other profiles in our sample too. On the contrary, the high quantity (49.2% and moderate quantity (55.6%) profiles in our study, which have relatively similar characteristics as their strongly motivated and moderately motivated profile were moderately unstable. In our sample, the high-quality profile lost most of its members with an increase in grade. As suggested by Gillet et al. (2017) probably having high quantity motivation could not be very useful given that the high quantity profile, in which members had equally high scores of the motivational constructs, is unstable. When the stability of the high quantity profile is compared with that of the quality profiles, it is noted that although some combinations of the forms of motivation (like in extrinsic profile and grade introjected profiles) may seem disadvantageous when critically examined due to low levels of intrinsic motivation and self-determination, these profiles in the sample are relatively stable. This suggests that perhaps students in quantity profiles (especially high and moderate profiles) have not crystallised their motivation behavioural regulation (Gillet et al., 2017) in physics learning. Unfortunately, the high quantity and moderate quantity profiles contain a significant large number of students.

More so, the transition of most members into grade introjected profile and EM profile in 11^{th} grade is not very surprising. Although we had expected more students to transition into primary-intrinsic profile, this was not the case. The increase in mean in grade motivation in the 11^{th} grade explains such this transition trend. Perhaps, due to the highly grade demanding culture of most Ugandan schools, students get overwhelmed and decide to focus of getting better physics grades. Clearly, the fact that none of the grade introjected profile members transitioned into the primarily intrinsic profile indicated the dampening effect of increasing grade motivation on intrinsic motivation.

In regard to within person stability in (Meta)cognitive learning strategy use profiles, as earlier stated in Kwarikunda et al. (2021) motivation profiles have a significant likelihood membership prediction on (Meta)cognitive learning strategy use profile. Due to the changes noted in students' motivation (Figure 7.2), we expected that there could be transitions of membership within the (Meta)cognitive learning strategy use profiles too. On conducting LTA, indeed results revealed that within person changes in terms of profile membership in this profile occurred. More precisely, the deep-level (92.1%) and surface-level learning profiles (72.1%) were the most stable profiles in the sample. Although competent users had the highest number of members at T_1, this profile lost most of its members to surface-level learners' profile at T_2 and to struggling users profile but not deep-level learners' profile. Such a trend in transition indicates that competent users are likely not to have an improvement in their learning strategy repertoire, given that the members lost are into profiles which use mostly rote learning and surface-level learning strategies that do not foster lifelong learning. Perhaps, could the competent users profile contain students who could benefit mostly from training in (Meta)cognitive learning strategy use, with focus on deep-level learning strategy use? We can't tell unless an intervention study in such is conducted. Additionally, this transition pattern clearly indicates that using all the learning strategies is not quite adaptable, given that less than

15% of these learners transitioned into the deep-level learning profile. Also, the increasing size profile of struggling users at T_2 needs immediate attention if lifelong physics learning is to be fostered.

Nevertheless, if students' (meta)cognitive learning strategy use is to be developed towards deep-level learning strategies, results from the predictive analyses indicate strong effects of perceived autonomy support and individual interest on the likelihood of membership into the deep-level learning profile, as compared to the predictive effects of age and gender. Because few associations were noted with regard to age and profile membership, and thus we could suggest that teachers focus less on students' age while emphasizing the (Meta)cognitive learning's strategies during instruction. Although gender has predicted the students' likelihood into the competent and surface-level learning profiles, it is not surprising given that previous studies have indicated that mostly girls tend to use all learning strategies equally (Rogiers et al., 2019) until when tasks become harder that some girls will shift to rehearsal strategies (Duncan & McKeachie, 2005).

7.5.1 Limitations

Although the present study provides a window for understanding with-in person and with-in sample stability of students' motivation and (Meta)cognitive learning use over time, we cannot draw conclusions of causality. The results of the current study are also limited to Physic learning. A similar study could be conducted in other STEM subjects. Even though possible predictive effects of likelihood membership into the (Meta)cognitive learning strategy profiles were examined, no explanatory relation with possible learner outcomes such as achievement, and relatedness was done. Thus, we recommend an explanatory study to examine the validity of the metacognitive learning strategy use profile with learner outcomes. Further, given the trends of transitions in the present study, a future study that employs an experimental intervention approach to examine possible effects of (Meta)cognitive learning strategy training could be done. Results from such a study could be practically informative given that the present study indicates that students (Meta)cognitive learning strategy profiles are unstable, with most students transitioning into profiles associated with poor achievement (Corpus & Wormington, 2014; Wormington et al., 2012) and surface-level learning (Schiefele, 1991).

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References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/TAC.1974.1100705

Asparouhov, T., & Muthen, B. (2007). Testing for informative weights and weights trimming in multivariate modeling with survey data. *Proceedings of the 2007 JSM meeting in Salt Lake City, Utah, Section on Survey Research Methods*.

Asparouhov, T., & Muthén, B. (2014). Auxiliary variables in mixture modeling: Three-step approaches using m plus. *Structural equation modeling: A multidisciplinary Journal*, *21*(3), 329–341.

Bouffard, T., Marcoux, M.-F., Vezeau, C., & Bordeleau, L. (2003). Changes in self-perceptions of competence and intrinsic motivation among elementary schoolchildren. *British journal of educational psychology*, *73*(2), 171–186.

Chittum, J. R., & Jones, B. D. (2017). Identifying pre–high school students' science class motivation profiles to increase their science identification and persistence. *Journal of Educational Psychology*, *109*(8), 1163.

Chow, S. J., & Yong, B. C. S. (2013). Secondary school students' motivation and achievement in combined science. *Online Submission*, *3*(4), 213–228.

Collins, L., & Lanza, S. (2010). *Latent class and latent transition analysis: With appli- cations in the social, behavioural, and health sciences.* New York, NY: Wiley.

Corpus, J. H., McClintic-Gilbert, M. S., & Hayenga, A. O. (2009). Within-year changes in children's intrinsic and extrinsic motivational orientations: Contextual predictors and academic outcomes. *Contemporary Educational Psychology*, *34*(2), 154–166.

Corpus, J. H., & Wormington, S. V. (2014). Profiles of intrinsic and extrinsic motivations in elementary school: A longitudinal analysis. *The Journal of Experimental Education*, *82*(4), 480–501.

Davis-Kean, P. E., Huesmann, L. R., Jager, J., Collins, W. A., Bates, J. E., & Lansford, J. E. (2008). Changes in the relation of self-efficacy beliefs and behaviors across development. *Child Development*, *79*(5), 1257–1269.

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, *11*(4), 227–268.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian psychology/Psychologie canadienne*, *49*(3), 182.

Duncan, T. G., & McKeachie, W. J. (2005). The making of the motivated strategies for learning questionnaire. *Educational psychologist*, *40*(2), 117–128.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, *53*(1), 109–132.

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed.

Ekatushabe, M., Kwarikunda, D., Muwonge, C. M., Ssenyonga, J., & Schiefele, U. (2021). Relations between perceived teacher's autonomy support, cognitive appraisals and boredom in physics learning among lower secondary school students. *International Journal of STEM Education*, *8*(1), 1–15.

Ekatushabe, M., Nsanganwimana, F., Muwonge, C. M., & Ssenyonga, J. (2021). The relationship between cognitive activation, self-efficacy, achievement emotions and (meta) cognitive learning strategies among ugandan biology learners. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(3), 247–258.

Filippello, P., Buzzai, C., Costa, S., Orecchio, S., & Sorrenti, L. (2020). Teaching style and academic achievement: The mediating role of learned helplessness and mastery orientation. *Psychology in the Schools*, *57*(1), 5–16.

Gillet, N., Morin, A. J., & Reeve, J. (2017). Stability, change, and implications of students' motivation profiles: A latent transition analysis. *Contemporary Educational Psychology*, *51*, 222–239.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire ii: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159–1176.

Green, J., Martin, A. J., & Marsh, H. W. (2007). Motivation and engagement in english, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences*, *17*, 269–279.

Guay, F., Ratelle, C. F., & Chanal, J. (2008). Optimal learning in optimal contexts: The role of self-determination in education. *Canadian psychology/Psychologie canadienne*, *49*(3), 233.

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion*, *34*(4), 371–383.

Hong, W., Bernacki, M. L., & Perera, H. N. (2020). A latent profile analysis of undergraduates' achievement motivations and metacognitive behaviors, and their relations to achievement in science. *Journal of Educational Psychology*, *112*(7), 1409.

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1–55.

Hunt, T., Muwonge, C., Ashraf, F., Asanjarani, F., Kotera, Y., Vione, K., Sheffield, D., Mir, R., & Waldron, M. (2021). Psychological barriers in maths education: Insights from iran, pakistan, and uganda. https://doi.org/10.13140/RG.2.2.36106.59844/1

Kwarikunda, D., Schiefele, U., Muwonge, C. M., & Ssenyonga, J. (2022). Profiles of learners based on their cognitive and meta cognitive learning strategy use: Occurrence and relations with gender, intrinsic motivation, and perceived autonomy support. *Humanities and social sciences communication*, *9*, 337.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in uganda. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 435–446.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2021). Secondary school students' motivation profiles for physics learning: Relations with cognitive learning strategies, gender, attitudes and individual interest. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(2), 197–210.

Lazarides, R., Dietrich, J., & Taskinen, P. H. (2019). Stability and change in students' motivational profiles in mathematics classrooms: The role of perceived teaching. *Teaching and Teacher Education*, *79*, 164–175.

Lazarides, R., Rubach, C., & Ittel, A. (2016). Motivational profiles in mathematics: What role do gender, age and parents' valuing of mathematics play? *International Journal of Gender, Science and Technology*, *8*(1), 124–143.

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of educational psychology*, *97*(2), 184.

Liu, W. C., Wang, C. K. J., Kee, H. C., Koh, C., Lim, B. S. C., & Chua, L. (2014). College students' motivation and learning strategies profiles and academic achievement: A self-determination theory approach. *Educational Psychology*, *34*(3), 338–353.

Lubke, G., & Muthén, B. O. (2007). Performance of factor mixture models as a function of model size, covariate effects, and class-specific parameters. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(1), 26–47.

Morin, A. J., & Wang, J. C. (2016). A gentle introduction to mixture modeling using physical fitness performance data. John Wiley & Sons.

Muthén, B. (2003). Statistical and substantive checking in growth mixture modeling: Comment on bauer and curran (2003).

Muthén, L. K., & Muthen, B. (2017). *Mplus user's guide: Statistical analysis with latent variables, user's guide*. Muthén & Muthén.

Muwonge, C. M., Schiefele, U., Ssenyonga, J., & Kibedi, H. (2017). Self-regulated learning among teacher education students: Motivational beliefs influence on the use of metacognition. *Journal of Psychology in Africa*, *27*(6), 515–521.

Muwonge, C. M., Ssenyonga, J., Kibedi, H., & Schiefele, U. (2020). Use of self-regulated learning strategies among teacher education students: A latent profile analysis. *Social Sciences & Humanities Open*, *2*(1), 100037.

Nylund-Gibson, K., Grimm, R., Quirk, M., & Furlong, M. (2014). A latent transition mixture model using the three-step specification. *Structural Equation Modeling: A Multidisciplinary Journal*, *21*(3), 439–454.

Oga-Baldwin, W., & Fryer, L. K. (2018). Schools can improve motivational quality: Profile transitions across early foreign language learning experiences. *Motivation and Emotion*, *42*(4), 527–545.

Pintrich, P. R., et al. (1991). A manual for the use of the motivated strategies for learning questionnaire (mslq).

Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational psychology review*, *16*(4), 385–407.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: A systematic review of 12 years of educational research. *Studies in science education*, *50*(1), 85–129.

Ratelle, C. F., Guay, F., Vallerand, R. J., Larose, S., & Senécal, C. (2007). Autonomous, controlled, and amotivated types of academic motivation: A person-oriented analysis. *Journal of educational psychology*, *99*(4), 734.

Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motivation and emotion*, *28*(2), 147–169.

Roeser, R. W., & Midgley, C. (1997). Teachers' views of issues involving students' mental health. *The Elementary School Journal*, *98*(2), 115–133.

Rogiers, A., Merchie, E., & Van Keer, H. (2019). Learner profiles in secondary education: Occurrence and relationship with performance and student characteristics. *The Journal of Educational Research*, *112*(3), 385–396.

Rotgans, J. I. (2015). Validation study of a general subject-matter interest measure: The individual interest questionnaire (iiq). *Health Professions Education*, *1*(1), 67–75.

Ryan, R., & Deci, E. (2004). Autonomy is no illusion: Selfdetermination theory and the empirical study of authenticity, awareness and will. chapter 28: 449-479.

Ryan, R., & Deci, E. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299–323.

Schiefele, U. (1999). Interest and learning from text. *Scientific studies of reading*, *3*(3), 257–279.

Schöber, C., Schütte, K., Köller, O., McElvany, N., & Gebauer, M. M. (2018). Reciprocal effects between self-efficacy and achievement in mathematics and reading. *Learning and Individual Differences*, *63*, 1–11.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics*, 461–464.

Sclove, S. L. (1987). Application of model-selection criteria to some problems in multivariate analysis. *Psychometrika*, *52*(3), 333–343.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental psychology*, *42*(1), 70.

Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. (2004). Supporting autonomy in the classroom: Ways teachers encourage student decision making and ownership. *Educational psychologist*, *39*(2), 97–110.

Talsma, K., Schüz, B., Schwarzer, R., & Norris, K. (2018). I believe, therefore i achieve (and vice versa): A meta-analytic cross-lagged panel analysis of self-efficacy and academic performance. *Learning and Individual Differences*, *61*, 136–150.

Vallerand, R. J. (1997). Toward a hierarchical model of intrinsic and extrinsic motivation. In *Advances in experimental social psychology* (pp. 271–360). Elsevier.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of educational psychology*, *101*(3), 671.

Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political analysis*, *18*(4), 450–469.

Wang, J., & Wang, X. (2012). *Structural equation modeling with mplus: Methods and applications*. Wiley.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary educational psychology*, *25*(1), 68–81.

Wigfield, A., & Eccles, J. S. (2002). The development of competence beliefs, expectancies for success, and achievement values from childhood through adolescence. *Development of achievement motivation*, 91–120.

Wormington, S. V., Corpus, J. H., & Anderson, K. G. (2012). A person-centered investigation of academic motivation and its correlates in high school. *Learning and Individual Differences*, *22*(4), 429–438.

Xie, K., Vongkulluksn, V. W., Cheng, S.-L., & Jiang, Z. (2022). Examining high-school students' motivation change through a person-centered approach. *Journal of Educational Psychology*, *114*(1), 89.

Zhang, D., Fu, D., Liu, H., & Liu, L. (2018). Effect of perceived teacher's autonomy support on students' achievement: The mediating role of autonomy psychological need and intrinsic motivation. *Teach. Educ. Res*, *30*, 79–86.

Zhao, J., & Qin, Y. (2021). Perceived teacher autonomy support and students' deep learning: The mediating role of self-efficacy and the moderating role of perceived peer support. *Frontiers in psychology*, *12*, 2177.

CHAPTER 8

DISCUSSION AND CONCLUSIONS

8.1 General Discussion

The first goal of this thesis was to obtain a valid instrument that could be used to assess lower secondary school students' physics learning motivation. In this case, we adapted the Science Motivation Questionnaire- II, which was originally developed to assess college students' science learning motivation in the USA(Glynn et al., 2011). Using an existing instruments is convenient. However, such instruments should not be used without sufficient evidence of their ability to produce valid and reliable scores in the desired context (Salta & Koulougliotis, 2015) or else unreliable and invalid interpretations of the results can be done. More so, adaptation and validation of an existing instrument enables cross-cultural comparisons (Ardura & Pérez-Bitrián, 2018) of certain construct within the same subject domain and age group. Thus, in the first article, we adapted and later validated the modified SMQ-II to assess physics learning motivation in lower secondary school students.

Whilst using Confirmatory Factor Analyses (CFAs), we assessed whether the five-component structure of the physics version of the SMQ-II could be validated. Additionally, CFAs were used to examine whether the measurement structure underlying motivation to learn physics was equivalent within the subgroups corresponding to gender(Salta & Koulougliotis, 2015). Assessing measurement invariance within groups provides evidence upon which subsequent comparisons between these groups can be conducted or not (Kline, 2011). The results of the CFAs provided evidence supporting the measure construct validity and measurement invariance on the physics version of the SMQ-II, opening up the possibility of a reliable measurement of students' motivation to Physics learning within the Ugandan context and for reliable cross-cultural comparisons of the students' motivation. when a closer look at the mean scores of the motivation constructs in grade 8 students was done, it was revealed that grade motivation was the most highly scored motivation trait, unlike intrinsic motivation which scored the lowest. High levels of grade motivation have also been reported in studies that used Greek students (Salta & Koulougliotis, 2015), German students (Schumm & Bogner, 2016), and Spanish students(Ardura & Pérez-Bitrián, 2018). Although the subject domains in the above studies are different from that of the current study, such a trend in grade motivation can not be ignored. Probably, it could be that lower secondary school students are highly motivated to obtain good grades due to the high academic competitive nature of secondary schools as compared to other school levels(Corpus & Wormington, 2014). However, it is unclear if this high grade motivation is an indicator of content mastery or performance- oriented goals. Never the less, (Opolot-Okurut, 2010) suggests that high levels of grade motivation could be attributed to most secondary school teachers' approaches that mostly aim at motivating their students towards obtaining higher grades as compared to development of other motivation constructs.

Implications of the high grade motivation score where further revealed when patterns of students' physics motivation were examined. In article 2, a description of the various motivation patterns for physics learning whilst using our sample were revealed. However, there is a significant number of students who are members of the grade introjected profile in our sample- a profile that is less common in existing studies (e.g., Corpus & Wormington, 2014; Hayenga & Corpus, 2010). These students not only have high grade motivation but also high levels of reported self-efficacy as compared to other motivational construct under study. One would wonder why a student would want to pass a course highly without any need and curiosity to have a career in that course. Langenkamp (2010) poses that the high grade motivation could be as a result of the extremely high social pressure from parents and teachers on students to perform highly.

The present study contributes to motivation research literature by providing more insight not only in physics as a subject domain but also in developing countries. Cross-group comparisons reveal the similarity on one hand as well as diversity on the other hand in education systems. Clearly, although different studies have used person-centered approaches to examine relations between the various components of the Self-regulated learning framework ((e.g., Chittum & Jones, 2017; Corpus & Wormington, 2014; Hayenga & Corpus, 2010; Lazarides et al., 2016; Vansteenkiste et al., 2009a), the diversity that could be attributed to school, cultural, and domain-specific differences are observed. For instance, the difference in the number of motivational profiles even with in the same age group and the difference in the characteristics of the profiles that seem to have been labelled the same indicated motivation diversity.The literature and discussion section of article 2 further demonstrate the individual differences within various samples.

Additionally, in article 3, we explore the various combinations of lower secondary school students' learning strategy use. Precisely, four profiles of learners are revealed. Even though the mean score for critical thinking was the lowest in our sample (see Results section 6.3.1), PCAs reveal a sample of students who prefer use of deep-level learning strategies during physics learning. Studies (e.g., Karlen, 2016) have highlighted the importance of deep- level learning for academic achievement. In terms of the number of profiles, similar findings were found in previous studies (e.g., Karlen, 2016; Merchie & Van Keer, 2014; Zheng et al., 2020). However, as discussed in section 6.4 and 6.2, the results of the present study are unique in the nature of the profiles. The presence of struggling user profile in our sample as compared to other studies could also be due to the cultural and age differences as compared to other studies. Never the less, our study findings conform to the suggestions that elaboration could be the basic learning strategies used by most high school students on developing countries(Akyol et al., 2010; Ekatushabe, Nsanganwimana, et al., 2021; King & Areepattamannil, 2014).

Further, the malleable nature of not only motivation but also learning strategies use and perceived autonomy support were confirmed in article 4. Much as some constructs of motivation and learning strategies use were increasing in mean score, over all students' physics motivation decreases as they move form one grade to another. More so, their choice for learning strategies to use changes from adaptive to more maladaptive learning strategies that promote more surface-level learning. Clearly, the increase in grade motivation and use of rehearsal strategies as students advance from one grade to another is of concern. Previous researches indicate that as students advance from on educational level to another, there is a possible likelihood of developing a learning strategy repertoire, which is significantly influenced by the learners level of motivation, autonomy, task difficulty, and previous achievement (Gillet et al., 2017; Kwarikunda et al., 2020; Zhao & Qin, 2021).

Contrary to other studies that used the adapted version of the SMQII to assess motivation in secondary school students(e.g., Ardura & Pérez-Bitrián, 2018; Salta & Koulougliotis, 2015; Schumm & Bogner, 2016), there were no statistically significant differences obtained between gender for the components of physics motivation in 8th grade students. Similar results were reported by Ekatushabe, Kwarikunda, et al. (2021) for the component of physics self-efficacy in lower secondary school students. Our findings, in part, reveal that female secondary school students are equally motivated to learn Physics just like their male counterparts at-least within the first year of their secondary school. However, as students advance from 8th grade to other grades , significant gender differences begin to occur. As indicated in table**??**, results of the longitudinal study show that as students advance to a higher grade, gender differences in physics career motivation and self-determination in favour of boys manifest. These differences further extend into the choice for the various learning strategies used during physics learning. There occurs a shift in the use of elaboration strategies and rehearsal strategies. In the lower grade, girls prefer the use of elaboration strategies. However, as they advance to higher grade, they prefer use of rehearsal strategies, whilst boys prefer elaboration strategies.

These gender differences further influence the distribution of students into the various motivation and learning strategies use profiles. The shift in choice of learning strategies by the female students resulted into an increased likelihood of female students' membership into the maladaptive learning profile. Although Rogiers et al. (2019) suggests that girls mostly tend to use all learning strategies equally, one one hand, based on the results in article 4, we partly agree with him for only the first year of secondary school especially in the physics context. One the other hand, we differ with Rogiers et al. (2019) and agree with Duncan and McKeachie (2005) that until physics learning tasks become complex as students move from one grade to another, most girls would shift to repeated use of rehearsal strategies in preference to other cognitive and metacognitive learning strategies.

The relationship between interest and motivation, and interest and learning strategies use has been elaborated in articles 1 and 4. In article 1, interest predicted students' motivation to learn Physics in Uganda with a high variance in intrinsic motivation and self-determination as compared with other motivational variables that . Our findings are in line with those of Bye et al. (2007). Usually, interest is the driving force behind intrinsic motivation (Schiefele, 1991), with a motivated student likely to display autonomy and employ self-initiated exploratory strategies (Schiefele, 1991), unlike uninterested students who rely on extrinsic motivation and instructions from the teachers as they seek external signs of work. Consequently, the uninterested learners cannot self-regulate their learning, which may result in low achievement in Physics. Additionally, the stable nature of individual interest, as suggested by Schiefele (1991, 1999) and Schiefele et al. (1992) has been demonstrated. Individual interest is not only stable in reading comprehension but also during physics learning.

8.2 Limitations

The findings of the present study should be interpreted in light of the limitations discussed below. Recommendations for further studies have also been highlighted.

8.2.1 Methodological Limitations

First, questionnaires were used to collect data. Such self-report measures may be subject to social desirability and self-report bias (Gillet et al., 2017; Greene, 2015; Rotgans, 2015). Whilst some students tend to self-report their motivation in a more positive light according to beliefs of social desirability, it is unclear whether such self-report bias may afflict demotivated versus motivated students differently (Xie et al., 2022). Demotivated students may be embarrassed to report their low motivation and end up over reporting their motivation levels. Future studies can employ a mixed-methods approach.

Secondly, the SMQ-II had low reliabilities. Such low reliability levels may be due to the use of few items to measure each sub-constructs (Vallerand et al., 1992). Also, such measurement errors could be attributed to the nature of the schools (semi-rural) we selected as compared with those used in the other studies were viewed (Kwarikunda et al., 2020). The implication of such measurement errors is that they could be one contributing factor for some of the instability in profile membership (Xie et al., 2022). While taking into consideration suggestions made by Komperda et al. (2020), it is important for future researchers to further assess the construct validity of the Physics version of the SMQII.

Thirdly, although article 4 provides a window for understanding with-in person and with-in sample stability of students' motivation and (Meta) cognitive learning use over time, we cannot draw conclusions of causality between students' interest, assessed motivation dimensions and their cognitive learning strategy use since only two waves of data were collected. Additionally, the results of the current study were also limited to Physic learning. A similar study could be conducted in other STEM subjects such as Biology and Chemistry.

8.2.2 Conceptual Limitations

Although the current study aimed at examining the relationship between interest, motivation, and learning strategy use during physics learning, much of the analyses were data driven. Thus, not much information from the results supports theoretical relations between the variables, especially for physics education. For the future, a similar theory-driven study could be conducted to explore the various theory-driven relationships between these variables during physics learning.

Secondly, the relationships between the present study variables and physics achievement in lower secondary school students were not examined. We could not collect achievement data due to coordination reasons. More so, most physics classes where at diverse levels of the syllabus coverage. It would be interesting for future research to examine the links between the various motivation and cognitive strategy profiles with students' physics achievement.

Lastly, although the self- regulation of learning framework encompasses mostly motivation emotions and cognitive and metacognitive strategies subcomponents (Puustinen & Pulkkinen, 2001), in the current study, no aspects of students' achievement emotions during Physics learning and their relations to motivation and cognitive learning strategy use where explored using a person-centered approach. A similar study is highly recommended, within the longitudinal research design framework.

8.3 Conclusion

This dissertation is a report of a data–driven study in which the relations between students' interest, motivation and learning strategy use during physics learning were explored. In the first article, an instrument that could be used to assess student's physics learning motivation whilst using lower secondary school students was evaluated. More so, the predictive role of interest to students' learning motivation was assessed. More so no statistically significant differences in students' motivation were found. In the second manuscript, various patterns of 8^{th} grade students' physics motivation, and the relations between these patterns and students' gender, individual interest, attitudes towards physics learning, and cognitive and metacognitive learning strategy use were assessed. six profiles of students' motivation for Physics learning were found with significant differences on cognitive learning strategy usage. More so, unlike gender, students' attitudes towards Physics learning and individual interest predicted profile membership. Students with low attitudes towards Physics learning and low individual interest were more likely to be placed in low-quantity and mostly extrinsically motivated profiles. On one hand, whilst students' higher individual interest scores increased their likelihood of membership into the primarily intrinsically motivated profile, higher attitudes towards physics learning increased their likelihood of membership into the high-quantity motivation profile one the other hand.

In article 3, results revealed that unlike critical thinking, students use mostly elaboration and metacognitive self-regulating strategies during Physics learning. Thus, it could be concluded that elaboration is a basic cognitive learning strategy used by lower secondary students during physics learning. More so, significant gender differences were noted in students use of elaboration and organisation physics learning strategies in favour of girls. On examining the various combinations of students cognitive and metacognitive learning strategies that 8^{th} grade students use, person-centered analyses revealed four distinct learner profiles that differed significantly in intrinsic motivation and perceived autonomy support. In Article 4, an examination of within-person and within-sample stability in motivation and metacognitive learning strategy use during physics learning secondary school students across a 2-year period indicated a gradual decrease in students' motivation. Notably, was the decrease in students' career motivation and self- determination with lowest means observed among girls. In terms of changes in students cognitive and metacognitive strategy use, the use of deep-level learning strategies decreases whilst that of surface-level learning strategies increased. On evaluating with-in sample stability, Latent profile transition analyses revealed the same number of motivation and metacognitive learning strategy profiles as in Kwarikunda et al. (2021) and Kwarikunda et al. (2022) respectively, characterized by similar configurations, revealing configured and structural similarity (Collins & Lanza, 2010; Gillet et al., 2017). On analysis of the with-in profile stability, results show that the motivation and metacognitive learning strategies use profiles remain moderately to highly stable over time in.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control*, *19*(6), 716–723.

Akyol, G., Sungur, S., & Tekkaya, C. (2010). The contribution of cognitive and metacognitive strategy use to students' science achievement. *Educational Research and Evaluation*, *16*(1), 1–21.

Amunga, J. K., Amadalo, M. M., & Musera, G. (2011). Disparities in the physics academic achievement and enrolment in secondary schools in western province: Implications for strategy renewal. *Problems of Education in the 21st Century*, *31*, 18.

Angell, C., Guttersrud, Ø., Henriksen, E. K., & Isnes, A. (2004). Physics: Frightful, but fun. pupils' and teachers' views of physics and physics teaching. *Science education*, *88*(5), 683–706.

Ardura, D., & Pérez-Bitrián, A. (2018). The effect of motivation on the choice of chemistry in secondary schools: Adaptation and validation of the science motivation questionnaire ii to spanish students. *Chemistry Education Research and Practice*, *19*(3), 905–918.

Ardura, D., & Pérez-Bitrián, A. (2019). Motivational pathways towards academic achievement in physics & chemistry: A comparison between students who opt out and those who persist. *Chemistry education research and practice*, *20*(3), 618–632.

Asiimwe, J. A. (2013). Compulsory science policy: Enhancing gender equality in education? a case study of academic achievement in uganda. *MIER Journal of Educational Studies Trends and Practices*, 183–194.

Asparouhov, T., & Muthen, B. (2007). Testing for informative weights and weights trimming in multivariate modeling with survey data. *Proceedings of the 2007 JSM meeting in Salt Lake City, Utah, Section on Survey Research Methods*.

Asparouhov, T., & Muthén, B. (2014). Auxiliary variables in mixture modeling: Three-step approaches using m plus. *Structural equation modeling: A multidisciplinary Journal*, *21*(3), 329–341.

Bandura, A. (1981). Self-referent thought: A developmental analysis of self-efficacy. *Social cognitive development: Frontiers and possible futures*, *200*(1), 239.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*(23-28).

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual review of psychology*, *52*(1), 1–26.

Bandura, A., et al. (2006). Guide for constructing self-efficacy scales. *Self-efficacy beliefs of adolescents*, *5*(1), 307–337.

Bandura, A., Freeman, W. H., & Lightsey, R. (1999). Self-efficacy: The exercise of control.

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International journal of science education*, *30*(8), 1075–1093.

Bidjerano, T. (2005). Gender differences in self-regulated learning. *Online Submission*.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science education*, *84*(6), 740–756.

Board, U. N. E. (2017). Statement of release of 2017 uce examination results.

Bouckenooghe, D., Cools, E., De Clercq, D., Vanderheyden, K., & Fatima, T. (2016). Exploring the impact of cognitive style profiles on different learning approaches: Empirical evidence for adopting a person-centered perspective. *Learning and Individual Differences*, *51*, 299–306.

Bouffard, T., Marcoux, M.-F., Vezeau, C., & Bordeleau, L. (2003). Changes in self-perceptions of competence and intrinsic motivation among elementary schoolchildren. *British journal of educational psychology*, *73*(2), 171–186.

Britner, S. L., & Pajares, F. (2001). Self-efficacy beliefs, motivation, race, and gender in middle school science. *Journal of women and Minorities in Science and Engineering*, *7*(4).

Bye, D., Pushkar, D., & Conway, M. (2007). Motivation, interest, and positive affect in traditional and nontraditional undergraduate students. *Adult education quarterly*, *57*(2), 141–158.

Chang, Y., & Yuan, C. (2008). Gender differences in science achievement, science self-concept, and science values. *Proceedings of the IRC, Chinese Taipei*.

Chittum, J. R., & Jones, B. D. (2017). Identifying pre–high school students' science class motivation profiles to increase their science identification and persistence. *Journal of Educational Psychology*, *109*(8), 1163.

Chow, S. J., & Yong, B. C. S. (2013). Secondary school students' motivation and achievement in combined science. *Online Submission*, *3*(4), 213–228.

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental and Science Education*, *6*(2), 141–159.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Lawrence Erlbaum.

Collins, L., & Lanza, S. (2010). *Latent class and latent transition analysis: With appli- cations in the social, behavioural, and health sciences.* New York, NY: Wiley.

Corpus, J. H., McClintic-Gilbert, M. S., & Hayenga, A. O. (2009). Within-year changes in children's intrinsic and extrinsic motivational orientations: Contextual predictors and academic outcomes. *Contemporary Educational Psychology*, *34*(2), 154–166.

Corpus, J. H., & Wormington, S. V. (2014). Profiles of intrinsic and extrinsic motivations in elementary school: A longitudinal analysis. *The Journal of Experimental Education*, *82*(4), 480–501.

Csikszentmihalyi, M., & Nakamura, J. (2014). The dynamics of intrinsic motivation: A study of adolescents. In *Flow and the foundations of positive psychology* (pp. 175–197). Springer.

Davis-Kean, P. E., Huesmann, L. R., Jager, J., Collins, W. A., Bates, J. E., & Lansford, J. E. (2008). Changes in the relation of self-efficacy beliefs and behaviors across development. *Child Development*, *79*(5), 1257–1269.

Deci, E. L. (1975). The intrinsic motivation of behavior. In *Intrinsic motivation* (pp. 93–125). Springer.

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, *11*(4), 227–268.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian psychology/Psychologie canadienne*, *49*(3), 182.

Dowson, M., & McInerney, D. M. (1998). Cognitive and motivational determinants of students' academic performance and achievement: Goals, strategies, and academic outcomes in focus.

Duncan, T. G., & McKeachie, W. J. (2005). The making of the motivated strategies for learning questionnaire. *Educational psychologist*, *40*(2), 117–128.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of psychology*, *53*(1), 109–132.

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed.

Ekatushabe, M., Kwarikunda, D., Muwonge, C. M., Ssenyonga, J., & Schiefele, U. (2021). Relations between perceived teacher's autonomy support, cognitive appraisals and boredom in physics learning among lower secondary school students. *International Journal of STEM Education*, *8*(1), 1–15.

Ekatushabe, M., Nsanganwimana, F., Muwonge, C. M., & Ssenyonga, J. (2021). The relationship between cognitive activation, self-efficacy, achievement emotions and (meta) cognitive learning strategies among ugandan biology learners. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(3), 247–258.

Filippello, P., Buzzai, C., Costa, S., Orecchio, S., & Sorrenti, L. (2020). Teaching style and academic achievement: The mediating role of learned helplessness and mastery orientation. *Psychology in the Schools*, *57*(1), 5–16.

Frazier-Kouassi, S. (1999). *A psychological study of mathematics attitudes and achievement among female ivorian students*. Women in International Development, Michigan State University.

Gillet, N., Morin, A. J., & Reeve, J. (2017). Stability, change, and implications of students' motivation profiles: A latent transition analysis. *Contemporary Educational Psychology*, *51*, 222–239.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire ii: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159–1176.

Glynn, S., & Koballa, T. (2006). Motivation to learn in college science (p. 25-32). *J. J. Mintzes & WH Leonard (Eds.), Handbook of college science teaching. Arlington, VA: NSTA Press*.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(2), 127–146.

González, A., Fernández, M.-V. C., & Paoloni, P.-V. (2017). Hope and anxiety in physics class: Exploring their motivational antecedents and influence on metacognition and performance. *Journal of Research in Science Teaching*, *54*(5), 558–585.

Green, J., Martin, A. J., & Marsh, H. W. (2007). Motivation and engagement in english, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences*, *17*, 269–279.

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections from over 20 years of research. *Educational Psychologist*, *50*(1), 14–30.

Guay, F., Ratelle, C. F., & Chanal, J. (2008). Optimal learning in optimal contexts: The role of self-determination in education. *Canadian psychology/Psychologie canadienne*, *49*(3), 233.

Gudyanga, A., Adam, K., & Kurup, R. (2015). Zimbabwean female participation in physics: The influence of context on identity formation. *African Journal of Research in Mathematics, Science and Technology Education*, *19*(2), 172–184.

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion*, *34*(4), 371–383.

Heikkilä, A., Lonka, K., Nieminen, J., & Niemivirta, M. (2012). Relations between teacher students' approaches to learning, cognitive and attributional strategies, well-being, and study success. *Higher Education*, *64*(4), 455–471.

Hickendorff, M., Edelsbrunner, P. A., McMullen, J., Schneider, M., & Trezise, K. (2018). Informative tools for characterizing individual differences in learning: Latent class, latent profile, and latent transition analysis. *Learning and Individual Differences*, *66*, 4–15.

Hidi, S. (2001). Interest, reading, and learning: Theoretical and practical considerations. *Educational psychology review*, *13*(3), 191–209.

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of educational research*, *70*(2), 151–179.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, *41*(2), 111–127.

Hong, W., Bernacki, M. L., & Perera, H. N. (2020). A latent profile analysis of undergraduates' achievement motivations and metacognitive behaviors, and their relations to achievement in science. *Journal of Educational Psychology*, *112*(7), 1409.

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1–55.

Hunt, T., Muwonge, C., Ashraf, F., Asanjarani, F., Kotera, Y., Vione, K., Sheffield, D., Mir, R., & Waldron, M. (2021). Psychological barriers in maths education: Insights from iran, pakistan, and uganda. https://doi.org/10.13140/RG.2.2.36106.59844/1

Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned? *New directions for child and adolescent development*, *2005*(110), 85–94.

Jaen, M. C. A., & Baccay, E. S. (2016). Curiosity, motivation, attitude, gender, and mathematics performance. *The Normal Lights*, *10*(2).

Jurik, V., Gröschner, A., & Seidel, T. (2014). Predicting students' cognitive learning activity and intrinsic learning motivation: How powerful are teacher statements, student profiles, and gender? *Learning and individual differences*, *32*, 132–139.

Kahle, J. B. (1994). Research on gender issues in the classroom. *Handbook of research on science teaching and learning*, 542–557.

Kang, J., & Keinonen, T. (2018). The effect of student-centered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in science education*, *48*(4), 865–885.

Karlen, Y. (2016). Differences in students' metacognitive strategy knowledge, motivation, and strategy use: A typology of self-regulated learners. *The Journal of Educational Research*, *109*(3), 253–265.

Kaur, D., & Zhao, Y. (2017). Development of physics attitude scale (pas): An instrument to measure students' attitudes toward physics. *The Asia-Pacific Education Researcher*, *26*(5), 291–304.

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, *54*(5), 586–614.

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International journal of science education*, *29*(7), 871–893.

King, R. B., & Areepattamannil, S. (2014). What students feel in school influences the strategies they use for learning: Academic emotions and cognitive/meta-cognitive strategies. *Journal of Pacific Rim Psychology*, *8*(1), 18–27.

Komperda, R., Hosbein, K. N., Phillips, M. M., & Barbera, J. (2020). Investigation of evidence for the internal structure of a modified science motivation questionnaire ii (msmq ii): A failed attempt to improve instrument functioning across course, subject, and wording variants. *Chemistry Education Research and Practice*, *21*(3), 893–907.

Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European journal of psychology of education*, *14*(1), 23–40.

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International journal of science education*, *33*(1), 27–50.

Kusurkar, R. A., & Croiset, G. (2015). Autonomy support for autonomous motivation in medical education. *Medical education online*, *20*(1), 27951.

Kwarikunda, D., Schiefele, U., Muwonge, C. M., & Ssenyonga, J. (2022). Profiles of learners based on their cognitive and meta cognitive learning strategy use: Occurrence and relations with gender, intrinsic motivation, and perceived autonomy support. *Humanities and social sciences communication*, *9*, 337.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2020). The relationship between motivation for, and interest in, learning physics among lower secondary school students in uganda. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 435–446.

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2021). Secondary school students' motivation profiles for physics learning: Relations with cognitive learning strategies, gender, attitudes and individual interest. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(2), 197–210.

Kwesiga, J. C. (2002). *Women's access to higher education in uganda: Uganda's experience.* Fountain Publishers Limited.

Larson, R. W., & Rusk, N. (2011). Intrinsic motivation and positive development. *Advances in child development and behavior*, *41*, 89–130.

Lazarides, R., Dietrich, J., & Taskinen, P. H. (2019). Stability and change in students' motivational profiles in mathematics classrooms: The role of perceived teaching. *Teaching and Teacher Education*, *79*, 164–175.

Lazarides, R., Rubach, C., & Ittel, A. (2016). Motivational profiles in mathematics: What role do gender, age and parents' valuing of mathematics play? *International Journal of Gender, Science and Technology*, *8*(1), 124–143.

Leaper, C., Farkas, T., & Brown, C. S. (2012). Adolescent girls' experiences and gender-related beliefs in relation to their motivation in math/science and english. *Journal of youth and adolescence*, *41*(3), 268–282.

Lee, V. E., & Burkam, D. T. (1996). Gender differences in middle grade science achievement: Subject domain, ability level, and course emphasis. *Science Education*, *80*(6), 613–650.

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of educational psychology*, *97*(2), 184.

Linn, M. C. (2000). Designing the knowledge integration environment. *International Journal of Science Education*, *22*(8), 781–796.

Linnenbrink, E. A., & Pintrich, P. R. (2002). Motivation as an enabler for academic success. *School psychology review*, *31*(3), 313–327.

Linnenbrink-Garcia, L., Wormington, S. V., Snyder, K. E., Riggsbee, J., Perez, T., Ben-Eliyahu, A., & Hill, N. E. (2018). Multiple pathways to success: An examination of integrative motivational profiles among upper elementary and college students. *Journal of educational psychology*, *110*(7), 1026.

Liu, W. C., Wang, C. K. J., Kee, H. C., Koh, C., Lim, B. S. C., & Chua, L. (2014). College students' motivation and learning strategies profiles and academic achievement: A self-determination theory approach. *Educational Psychology*, *34*(3), 338–353.

Liu, W. C., Wang, C. K. J., Kee, Y. H., Koh, C., Lim, B. S. C., & Chua, L. (2014). College students' motivation and learning strategies profiles and academic achievement: A self-determination theory approach. *Educational Psychology*, *34*(3), 338–353.

Lubke, G., & Muthén, B. O. (2007). Performance of factor mixture models as a function of model size, covariate effects, and class-specific parameters. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(1), 26–47.

Manganelli, S., Cavicchiolo, E., Mallia, L., Biasi, V., Lucidi, F., & Alivernini, F. (2019). The interplay between self-determined motivation, self-regulated cognitive strategies, and prior achievement in predicting academic performance. *Educational Psychology*, *39*(4), 470–488.

McCutcheon, A. L. (1987). *Latent class analysis*. Sage.

Meece, J. L., & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *33*(4), 393–406.

Meece, M. G., Judith L.and Jones. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching*, *33*(393-406).

Merchie, E., & Van Keer, H. (2014). Using on-line and off-line measures to explore fifth and sixth graders' text-learning strategies and schematizing skills. *Learning and Individual Differences*, *32*, 193–203.

Merchie, E., Van Keer, H., & Vandevelde, S. (2014). Development of the text-learning strategies inventory: Assessing and profiling learning from texts in fifth and sixth grade. *Journal of Psychoeducational Assessment*, *32*(6), 533–547.

Metallidou, P., & Vlachou, A. (2007). Motivational beliefs, cognitive engagement, and achievement in language and mathematics in elementary school children. *International journal of psychology*, *42*(1), 2–15.

Morin, A. J., Meyer, J. P., Creusier, J., & Biétry, F. (2016). Multiple-group analysis of similarity in latent profile solutions. *Organizational Research Methods*, *19*(2), 231–254.

Morin, A. J., & Wang, J. C. (2016). A gentle introduction to mixture modeling using physical fitness performance data. John Wiley & Sons.

Muthén, B. (2003). Statistical and substantive checking in growth mixture modeling: Comment on bauer and curran (2003).

Muthén, B., & Muthén, L. K. (2000). Integrating person-centered and variable-centered analyses: Growth mixture modeling with latent trajectory classes. *Alcoholism: Clinical and experimental research*, *24*(6), 882–891.

Muthén, L. K., & Muthen, B. (2017). *Mplus user's guide: Statistical analysis with latent variables, user's guide*. Muthén & Muthén.

Muthén, L., & Muthén, B. (2017). Mplus user's guide: Statistical analysis with latent variables. statistical analysis with latent variables. version.

Muwonge, C. M., Schiefele, U., Ssenyonga, J., & Kibedi, H. (2017). Self-regulated learning among teacher education students: Motivational beliefs influence on the use of metacognition. *Journal of Psychology in Africa*, *27*(6), 515–521.

Muwonge, C. M., Ssenyonga, J., Kibedi, H., & Schiefele, U. (2020). Use of self-regulated learning strategies among teacher education students: A latent profile analysis. *Social Sciences & Humanities Open*, *2*(1), 100037.

Nagin, D. S. (2010). Group-based trajectory modeling: An overview. *Handbook of quantitative criminology*, 53–67.

Nagin, D. S., Nagin, D., et al. (2005). *Group-based modeling of development*. Harvard University Press.

Niemivirta, M. (1997). Gender differences in motivational-cognitive patterns of self-regulated learning.

Niemivirta, M., & Tapola, A. (2007). Self-efficacy, interest, and task performance: Within-task changes, mutual relationships, and predictive effects. *Zeitschrift für Pädagogische Psychologie*, *21*(3/4), 241–250.

Ning, H. K., & Downing, K. (2015). A latent profile analysis of university students' self-regulated learning strategies. *Studies in Higher Education*, *40*(7), 1328–1346.

Nylund-Gibson, K., Grimm, R., Quirk, M., & Furlong, M. (2014). A latent transition mixture model using the three-step specification. *Structural Equation Modeling: A Multidisciplinary Journal*, *21*(3), 439–454.

Obergriesser, S., & Stoeger, H. (2020). Students' emotions of enjoyment and boredom and their use of cognitive learning strategies–how do they affect one another? *Learning and Instruction*, *66*, 101285.

OECD. (2010). *Pisa 2009 results: Learning to learn. student engagement, strategies and practices (vol. iii)*.

Oga-Baldwin, W., & Fryer, L. K. (2018a). Schools can improve motivational quality: Profile transitions across early foreign language learning experiences. *Motivation and Emotion*, *42*(4), 527–545.

Oga-Baldwin, W., & Fryer, L. K. (2018b). Schools can improve motivational quality: Profile transitions across early foreign language learning experiences. *Motivation and Emotion*, *42*(4), 527–545.

Ong, E.-T., & Ruthven, K. (2009). The effectiveness of smart schooling on students' attitudes towards science. *Eurasia Journal of Mathematics, Science and Technology Education*, *5*(1), 35–45.

Oon, P.-T., & Subramaniam, R. (2011). On the declining interest in physics among students—from the perspective of teachers. *International journal of Science education*, *33*(5), 727–746.

Opolot-Okurut, C. (2010). Classroom learning environment and motivation towards mathematics among secondary school students in uganda. *Learning Environments Research*, *13*(3), 267–277.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International journal of science education*, *25*(9), 1049–1079.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of educational research*, *66*(4), 543–578.

Pajares, F., & Schunk, D. (2001). The development of academic self-efficacy. *Development of achievement motivation. United States*, *7*, 1–27.

Pintrich, P. R., et al. (1991). A manual for the use of the motivated strategies for learning questionnaire (mslq).

Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International journal of educational research*, *31*(6), 459–470.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In *Handbook of self-regulation* (pp. 451–502). Elsevier.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of educational Psychology*, *95*(4), 667.

Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational psychology review*, *16*(4), 385–407.

Pintrich, P. R., & Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom academic tasks. *Student perceptions in the classroom*, *7*(1), 149–183.

Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: Theory, research, and applications*. Prentice Hall.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (mslq). *Educational and psychological measurement*, *53*(3), 801–813.

Pintrich, P. R., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In *Development of achievement motivation* (pp. 249–284). Elsevier.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: A systematic review of 12 years of educational research. *Studies in science education*, *50*(1), 85–129.

Purdie, N., Hattie, J., & Douglas, G. (1996). Student conceptions of learning and their use of self-regulated learning strategies: A cross-cultural comparison. *Journal of educational psychology*, *88*(1), 87.

Puustinen, M., & Pulkkinen, L. (2001). Models of self-regulated learning: A review. *Scandinavian journal of educational research*, *45*(3), 269–286.

Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in south africa. *Teaching and teacher education*, *38*, 65–75.

Ratelle, C. F., Guay, F., Vallerand, R. J., Larose, S., & Senécal, C. (2007a). Autonomous, controlled, and amotivated types of academic motivation: A person-oriented analysis. *Journal of educational psychology*, *99*(4), 734.

Ratelle, C. F., Guay, F., Vallerand, R. J., Larose, S., & Senécal, C. (2007b). Autonomous, controlled, and amotivated types of academic motivation: A person-oriented analysis. *Journal of educational psychology*, *99*(4), 734.

Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motivation and emotion*, *28*(2), 147–169.

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of educational psychology*, *95*(2), 375.

Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In *Intrinsic and extrinsic motivation* (pp. 373–404). Elsevier.

Roeser, R. W., & Midgley, C. (1997). Teachers' views of issues involving students' mental health. *The Elementary School Journal*, *98*(2), 115–133.

Rogiers, A., Merchie, E., & Van Keer, H. (2019). Learner profiles in secondary education: Occurrence and relationship with performance and student characteristics. *The Journal of Educational Research*, *112*(3), 385–396.

Rotgans, J. I. (2015). Validation study of a general subject-matter interest measure: The individual interest questionnaire (iiq). *Health Professions Education*, *1*(1), 67–75.

Ryan, R. M., & Connell, J. P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *Journal of personality and social psychology*, *57*(5), 749.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, *55*(1), 68.

Ryan, R. M., & Deci, E. L. (2009). Promoting self-determined school engagement: Motivation, learning, and well-being.

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary educational psychology*, *61*, 101860.

Ryan, R., & Deci, E. (2004). Autonomy is no illusion: Selfdetermination theory and the empirical study of authenticity, awareness and will. chapter 28: 449-479.

Ryan, R., & Deci, E. (2008). A self-determination theory approach to psychotherapy: The motivational basis for effective change. *Canadian psychology/Psychologie canadienne*, *49*(3), 186.

Ryan, R., & Deci, E. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.

Saleh, S. (2014). Malaysian students' motivation towards physics learning. *European Journal of Science and Mathematics Education*, *2*(4), 223–232.

Salta, K., & Koulougliotis, D. (2015). Assessing motivation to learn chemistry: Adaptation and validation of science motivation questionnaire ii with greek secondary school students. *Chemistry Education Research and Practice*, *16*(2), 237–250.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299–323.

Schiefele, U. (1999). Interest and learning from text. *Scientific studies of reading*, *3*(3), 257–279.

Schiefele, U. (2009). Situational and individual interest. In *Handbook of motivation at school* (pp. 211–236). Routledge.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research.

Schöber, C., Schütte, K., Köller, O., McElvany, N., & Gebauer, M. M. (2018). Reciprocal effects between self-efficacy and achievement in mathematics and reading. *Learning and Individual Differences*, *63*, 1–11.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in science education*, *36*(1), 111–139.

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education*, *38*(3), 434–449.

Schunk, D. H. (1989). Social cognitive theory and self-regulated learning. In *Self-regulated learning and academic achievement* (pp. 83–110). Springer.

Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational psychologist*, *26*(3-4), 207–231.

Schunk, D., Pintrich, P., & Meece, J. (2008). Motivation in education 3rd ed upper saddle river.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics*, 461–464.

Sclove, S. L. (1987). Application of model-selection criteria to some problems in multivariate analysis. *Psychometrika*, *52*(3), 333–343.

Senécal, C., Julien, E., & Guay, F. (2003). Role conflict and academic procrastination: A self-determination perspective. *European journal of social psychology*, *33*(1), 135–145.

Shachar, H., & Fischer, S. (2004). Cooperative learning and the achievement of motivation and perceptions of students in 11th grade chemistry classes. *Learning and instruction*, *14*(1), 69–87.

Siddiqui, R., Anjum, A., & Hassan, A. (2020). Gender differences on perceived social support and psychological distress among university students.

Sidin, R. (2003). Pembudayaan sains dan teknologi: Satu cadangan piawai. *Jurnal Pendidikan*, *28*(2), 47–63.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental psychology*, *42*(1), 70.

Sjøberg, S., & Schreiner, C. (2010). *The rose project. an overview and key findings. rose publications.*

Slotte, V., Lonka, K., & Lindblom-Ylänne, S. (2001). Study-strategy use in learning from text. does gender make any difference? *Instructional Science*, *29*(3), 255–272.

Soenens, B., & Vansteenkiste, M. (2005). Antecedents and outcomes of self-determination in 3 life domains: The role of parents' and teachers' autonomy support. *Journal of youth and adolescence*, *34*(6), 589–604.

Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. (2004a). Supporting autonomy in the classroom: Ways teachers encourage student decision making and ownership. *Educational psychologist*, *39*(2), 97–110.

Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. (2004b). Supporting autonomy in the classroom: Ways teachers encourage student decision making and ownership. *Educational psychologist*, *39*(2), 97–110.

Stipek, D. J., et al. (1996). Motivation and instruction. *Handbook of educational psychology*, *1*, 85–113.

Stolk, J., & Harari, J. (2014). Student motivations as predictors of high-level cognitions in project-based classrooms. *Active Learning in Higher Education*, *15*(3), 231–247.

Talsma, K., Schüz, B., Schwarzer, R., & Norris, K. (2018). I believe, therefore i achieve (and vice versa): A meta-analytic cross-lagged panel analysis of self-efficacy and academic performance. *Learning and Individual Differences*, *61*, 136–150.

Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International journal of science education*, *27*(6), 639–654.

UNEB. (2017). Statement of release of 2017 uce examination results. https://uneb.ac.ug/

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary educational psychology*, *34*(1), 89–101.

Vallerand, R. J. (1997). Toward a hierarchical model of intrinsic and extrinsic motivation. In *Advances in experimental social psychology* (pp. 271–360). Elsevier.

Vallerand, R. J., Gauvin, L. I., & Halliwell, W. R. (1986). Effects of zero-sum competition on children's intrinsic motivation and perceived competence. *The Journal of Social Psychology*, *126*(4), 465–472.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Briere, N. M., Senecal, C., & Vallieres, E. F. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and psychological measurement*, *52*(4), 1003–1017.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009a). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of educational psychology*, *101*(3), 671.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009b). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of educational psychology*, *101*(3), 671.

Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political analysis*, *18*(4), 450–469.

Wang, J., & Wang, X. (2012). *Structural equation modeling with mplus: Methods and applications*. Wiley.

Wang, J., & Wang, X. (2019). *Structural equation modeling: Applications using mplus*. John Wiley & Sons.

Watt, H. M., Bucich, M., & Dacosta, L. (2019). Adolescents' motivational profiles in mathematics and science: Associations with achievement striving, career aspirations and psychological wellbeing. *Frontiers in Psychology*, *10*, 990.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary educational psychology*, *25*(1), 68–81.

Wigfield, A., & Eccles, J. S. (2002). The development of competence beliefs, expectancies for success, and achievement values from childhood through adolescence. *Development of achievement motivation*, 91–120.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of personality and social psychology*, *70*(4), 767.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in science education*, *38*(3), 321–341.

Wolters, C. A., & Pintrich, P. R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, english, and social studies classrooms. *Instructional science*, *26*(1), 27–47.

Wormington, S. V., Corpus, J. H., & Anderson, K. G. (2012). A person-centered investigation of academic motivation and its correlates in high school. *Learning and Individual Differences*, *22*(4), 429–438.

Xie, K., Vongkulluksn, V. W., Cheng, S.-L., & Jiang, Z. (2022). Examining high-school students' motivation change through a person-centered approach. *Journal of Educational Psychology*, *114*(1), 89.

Zamora, A., & Ardura, D. (2014). To what extent do high school physics students use their own mistakes to learn? an experience on self-regulation in a secondary school classroom. *Ensenanza de las Ciencias*, *32*(2), 253–268.

Zeyer, A. (2010). Motivation to learn science and cognitive style. *Eurasia Journal of Mathematics, Science and Technology Education*, *6*(2), 121–128.

Zhang, D., Fu, D., Liu, H., & Liu, L. (2018). Effect of perceived teacher's autonomy support on students' achievement: The mediating role of autonomy psychological need and intrinsic motivation. *Teach. Educ. Res*, *30*, 79–86.

Zhao, J., & Qin, Y. (2021). Perceived teacher autonomy support and students' deep learning: The mediating role of self-efficacy and the moderating role of perceived peer support. *Frontiers in psychology*, *12*, 2177.

Zheng, J., Xing, W., Zhu, G., Chen, G., Zhao, H., & Xie, C. (2020). Profiling self-regulation behaviors in stem learning of engineering design. *Computers & Education*, *143*, 103669.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational psychologist*, *25*(1), 3–17.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In *Handbook of self-regulation* (pp. 13–39). Elsevier.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, *41*(2), 64–70.

Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International journal of science education*, *25*(9), 1081–1094.

CHAPTER A

APPENDIX

A.1 Information Sheet

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INFORMATION SHEET

Study title

Attitudes, Interest, Motivation, and Use of Cognitive Learning Strategies among Lower secondary School Students towards Learning of Physics in Uganda.

Dear**participant** ,

You have been selected to participate in the study. This information sheet explains the research study, and your rights as a participant in the study. Please read it carefully and ask us any questions or concerns that you have. We shall truthfully answer them. You can also contact us for more information. We have provided our addresses above. Please remember that you are a volunteer. You can choose not to take part and if you join, you may quit at any time. There will be no penalty if you decide to quit the study.

Purpose of the study

The study will assess senior one and senior two students' attitudes, interests, motivation and learning strategies for learning physics.

Brief background to the study

The government of Uganda has invested a lot of resources in science education especially physics by constructing laboratories, buying equipment and materials for the laboratories, training and recruiting more physics teachers. However, students' performance in physics has been the worst for the last decade according to Uganda National Examinations Board (UNEB) statistics. Some of the reasons for this poor performance have been suspected to be the students attitudes, interest, motivation and how you learn physics. Although no study has been carried out to assess these factors. Therefore, We designed a research that will assess the attitudes, interests, motivation and learning methods students use to learn physics. We shall provide questionnaires for you to fill and invite you for a group discussion as means of data collection. The questionnaires will last for maximum thirty minutes.

Procedures

If you accept to participate in the study, we request you to please sign the consent form. You will be given a questionnaire. One member of the team will guide you through how to fill the questionnaire. Please fill the questionnaire truthfully without indicating your name or that of your school. After collecting the questionnaires, we will enter your responses in a data base and then analyze them. We will interpret the findings and develop manuscripts for publication. We might also present the findings in conferences around the world.

Risks or discomforts

For the participant, you will not face any risks.

Benefits

For the participants, there is no direct personal benefit from the study. However researchers can use the findings from this study to design interventions that can be used to improve on students' performance in physics.

Incentives or rewards for participating

For your time, we shall provide you a pen as a token for your time.

Participation

Your participation in this study is voluntary.

Protecting data confidentiality

For purposes of confidentiality, please do not include your name or that of your school on the questionnaire. The filled questionnaires and tape recordings of the group discussions will be stored in a locked drawer after we have analysed the data on it.

Duration of storage of data

The questionnaires and tapes will be stored for 10 years after the study. Thereafter, they will be destroyed under supervision of the project supervisors.

Protecting subject privacy during data collection

To ensure your privacy during the process of data collection, please do not write your name and that of your school anywhere on the questionnaire including the signature section. During voice recording, please do not say out your name. Use the codes on the participants name tag to identify them.

Right to refuse or withdraw from the study

You have a right to choose whether to participate or not to participate in the study. If you do not want to participate in the study, you will receive no penalty. When you decide to leave from the study, you will receive no penalty.

What happens if you leave the study?

You may discontinue participation at any time without from the study. There are no penalties that you will receive.

Who do I ask/call if I have questions or a problem?

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A.2 Consent Sheet

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INFORMED CONSENT

Title of the study: Attitudes, Interest, Motivation, and Use of Cognitive Learning Strategies among Lower secondary School Students towards Learning of Physics in Uganda.

What does your signature or thumbprint on this consent form mean?

Your signature on this form means that

- You have received a copy of the information sheet and have attended the information session about the study.
- You have been informed about this study's purpose, procedures, possible benefits and risks and you have clearly understood them.
- You have been given the chance to ask any questions about the study and you have been answered the questions clearly before you sign • You have voluntarily agreed to

participate in this study without coercion. You have understood that you can leave the study at any time without any consequences/ penalties or risks.

- You have accepted that the findings from the data can be published in any recognized journal and or be presented in any conference by the principal investigator and the project supervisor .

__________________________ __________________________

Signature of participant or Legally authorized representative Date, Place

__________________________ __________________________

Signature of person obtaining consent Date, Place

A.3 Questionnaire

A.3.1 Questionnaire for Interest

The following questions ask about your individual interest for physics class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible.

	not true for me	neutral	true for me	very true for me
1. I am very interested in physics				
2. Outside of school, I read a lot about physics				
3. I always look forward to my physics lessons because I enjoy them a lot				
4. I am interested in physics since I was young				
5. I watch a lot of physics related TV channels like discovery channel				
6. Later in my life I want to pursue a career in physics or physics related discipline for example doctors, engineers, teachers				
7. When I am reading something about physics or watching something about physics on TV, I am fully focused and at times i forget everything around me.				

A.3.2 Questionnaire for Physics Learning Motivation

The following questions ask about your motivation for physics class. Again, there are no right or wrong answers.

	Never	Rarely	Sometimes	Usually	Always
1. The physics I learn is relevant to my life					
2. I like to do better than other students on physics tests					
3. Learning physics is interesting					
4. Getting a good physics grade is important to me					
5. I put enough effort into learning physics					
6. I use different strategies to learn physics					
7. Learning physics will help me get a good job					
8. It is important that I get 80% or above in physics tests/ exams					
9. I am confident I will do well on physics tests					
10. Knowing physics will give me a job advantage.					
11. I spend a lot of time learning physics					
12. Learning physics makes my life more meaning full					
13. Understanding physics will benefit me in my career					
14. I am confident I will do well on physics experiments 15. I believe I can master physics knowledge and skills					

	Never	Rarely	Sometimes	Usually	Always
16. I prepare well for physics tests and practicals					
17. I am curious about discoveries in physics					
18. I believe I can earn 80% or above in physics tests and exams					
19. I enjoy learning physics					
20. I think about the grade I will get in physics					
21. I am sure I can understand physics					
22. I study hard to learn physics					
23. My career will involve physics					
24. Scoring high on physics tests and laboratory work					
25. I will use physics problem solving skills in my career					

A.3.3 Questionnaire for Learning Strategies Use

The following questions ask about your learning strategies for physics class. Answer the questions about how you study in this class as accurately as possible. If you think the statement is very true of you, tick 7; if a statement is not at all true of you, tick 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes your experiences.

	1 Not at all true	2	3	4	5	6	7 Very true
1. When I study physics, I outline the material to help me organise my thoughts							
2. During class time I often miss important points because I'm thinking of other things							
3. When reading physics, I make up questions to help focus my reading							
4. I often find myself questioning things I hear or read about physics to decide if I find them convincing							
5. When I study physics, I practice saying the material to myself over and over							
6. When I become confused about something I am reading in physics, I go back and try to figure it out							
7. When I study physics, I go through the readings and my class notes and try to find the most important ideas or points.							
8. I make good use of my study time for physics.							
9. If physics readings are difficult to understand, I change the way I read the material.							

	1 Not at all true	2	3	4	5	6	7 Very true
10. When studying for physics, I read my class notes over and over again.							
11. when a theory interpretation or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence							
12. I make simple charts, diagrams, or tables to help me organize physics course material.							
13. I treat the physics course material as a starting point and try to develop my own ideas about it.							
14. I find it hard to stick to a study schedule in physics							
15. When I study for physics class, I pull together information from different sources, such as lesson notes, readings, and discussions.							
16. I ask myself questions to make sure I understand the material I have been studying in this class.							
17. I try to change the way I study physics in order to fit the course requirements and the instructor's teaching style.							
18. Often I find that I have been reading for this physics class but don't know what it was all about							
19. I memorize key words to remind me of important concepts in physics class.							
20. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for physics course.							

	1 Not at all true	2	3	4	5	6	7 Very true
21. I try to relate ideas in physics to those in other courses whenever possible.							
22. When I study for physics, I go over my class notes and make an outline of important concepts							
23. When reading for physics , I try to relate the material to what I already know.							
24. I try to play around with ideas of my own related to what I am learning in physics.							
25. When I study for physics, I write brief summaries of the main ideas from the readings and my class notes.							
26. I try to understand the material in the physics class by making connections between the readings and the concepts from the lessons.							
27. Whenever I read or hear an assertion or conclusion in physics class, I think about possible alternatives.							
28. I make lists of important items for physics class and memorise the lists.							
29. When I study for physics, I set goals for myself in order to direct my activities in each study period.							
30. I try to apply ideas from physics readings in other class activities such as lessons and discussion							

A.3.4 Questionnaire for Perceived Teacher Autonomy Support

	Strongly disagree	*disagree*	*Mildly disagree*	*Neutral*	*mildly agree*	*Agree*	*Strongly agree*
1. I feel that my physics teacher provides me choices and option							
2. I feel I understand my physics teacher during the lessons							
3. I am able to be open with my physics teacher during class							
4. My physics teacher shows confidence in my ability to do well in physics test							
5. I feel like my physics teacher accepts me							
6. My physics teacher makes sure that I really understand the goals of learning physics and what to do to pass.							
7. My physics teacher encourages me to ask questions							
8. My physics teacher answers my questions fully and carefully							
9. I feel a lot of trust in my physics teacher							
10. My physics teacher listens to how I would like to do things							
11. My physics teacher handles students' emotions very well							
12. I feel that my physics teacher cares about me as a person							

	Strongly disagree	disagree	Mildly disagree	Neutral	mildly agree	Agree	Strongly agree
13. I don't feel very good about the way my physics teacher talks to me							
14. My physics teacher tries to understand how I see things before suggesting a new way to do things.							
15. I feel able to share my feelings with my physics teacher.							

A.3.5 Questionaire for Attitude towards Physics learning

Please read the statements below and truthfully indicate your level of agreement or disagreement by ticking the appropriate box. There are no right or wrong answers

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
1. Learning physic and physics related material is enjoyable to me					
2. Studying topics on physics in greater detail is very important					
3. My confidence level increases by doing physics experiments in the laboratory					
4. Physics is a boring subject for me					
5. The basic knowledge of physics is useful for every one					
6. The successful completion of a physics experiment excites me to do other experiments					
7. I will be happy if the practical work in physics is reduced so that I may devote more time in studying theory					
8. I am punctual with physics homework					
9. I wait eagerly for physics period					
10. I discuss physics with my friends					
11. I feel very pleased and satisfied on answering the questions in the physics class					

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
12. Laboratory work in physics improves individual productiveness					
13. I keep on practicing the problems done in the physics class till I attain good grades and physics knowledge					
14. I feel stressed in my physics class					
15. Active participation of students in practical and theory classes result in effective understanding of physics					
16. Absence of discussions in physics is responsible for not getting good marks					

A.4 Proof of Ethical Clearance

Universität Potsdam · Am Neuen Palais 10 · 14469 Potsdam

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Humanwissenschaftliche Fakultät
Institut für Psychologie
Frau Kwarikunda
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Ethikkommission
Vorsitzender
Prof. Dr. Dr. Rapp

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Datum: 03.03.2020

Endbescheid zu dem Antrag Nr. 86/2019

Sehr geehrte Frau Kwarikunda,

die Ethikkommission erhebt keine Einwände gegen das Forschungsprojekt

„Attitudes, Interest, Motivation, and Use of Cognitive Learning Strategies among Lower secondary School Students towards Learning of Physics in Uganda“

mit dem Hinweis, dass die Anmerkungen des Datenschutzbeauftragten zu beachten und zu bearbeiten sind.

Dem Votum liegt der Beschluss der Ethikkommission 8/83. Sitzung – 02.03.2020 - 31. Telefonkonferenz zu Grunde.

Ich wünsche Ihnen für die Durchführung Ihres Vorhabens viel Erfolg.

Mit freundlichen Grüßen

Prof. Dr. Dr. Rapp
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P.O. Box 1410, Mbarara Uganda. Tel: +256 485433795; Fax: +256 4854 20782
RESEARCH ETHICS COMMITTEE
E-mail: sec.rec@must.ac.ug

Our Ref: MUREC 1/7 **Date:** March 06, 2019

Ms. Diana Kwarikunda
Postgraduate student

Re: Submitted Protocol on "Attitudes, interest, motivation, and cognitive learning strategies of lower secondary school students towards Physics learning in Uganda" 04/10-18

Type: [√] Initial Application
[ ] Protocol Amendment
[ ] Letter of Amendment (LOA)
[] Continuing Review
[ ] Other, specify: ______________________

Mbarara University of Science & Technology
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RESEARCH ETHICS COMMITTEE
05 MAR 2020
APPROVED
VALID UNTIL DATE SHOWN ABOVE

Reference is made to the above protocol which was resubmitted to the Research Ethics Committee for reconsideration and approval under expedited review process.

It is noted that you have addressed all the concerns earlier raised by the Committee.

I am pleased to inform you that your study has been approved for a period of one year from **March 06, 2019** up to **March 05, 2020.**

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigator must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for review and approval prior to the activation of the changes. The REC application number assigned to the research should be cited in any correspondence.
3. Reports of unanticipated problems involving risks to participants or other must be submitted to the REC. New information that becomes available which could change the risk: benefit ratio must be submitted promptly for REC review.
4. Only approved consent forms are used in enrolment of participants. All consent forms signed by subjects and/or witness should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Regulations require review of an approved study not less than once per 12-month period. **Therefore, a continuing review application must be submitted to REC eight weeks prior to the above expiration date of March 05, 2020 in order to continue the study beyond the approved period.** Failure to submit a continuing review application in timely fashion may result in suspension or termination of the study, at which point new participants may not be enrolled and currently enrolled participants must be taken off the study.

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6. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of documents approved in the application:

Document	Language	Version
Proposal	English	Version 2
Protocol form	English	Version 2
Data Collection tools	English	**March 2019**
Consent form	English	**March 2019**

I wish you all the best.

Dr. Francis Bajunirwe
CHAIR,
MUST RESEARCH ETHICS COMMITTEE

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