EXPLORING PRESERVICE SCIENCE TEACHERS' ADAPTIVE EXPERTISE AND REFORMED BELIEFS ABOUT SCIENCE TEACHING AND LEARNING

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ABSTRACT

EXPLORING PRESERVICE SCIENCE TEACHERS' ADAPTIVE EXPERTISE AND REFORMED BELIEFS ABOUT SCIENCE TEACHING AND LEARNING

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The main purposes of the study are to explore (1)the level of preservice science teachers' adaptive expertise and reformed beliefs, (2) the differences between pre-service teachers' adaptive expertise and reformed beliefs about science teaching and learning in terms of their academic majors, (3) the differences between levels of years regarding adaptive skills and reformed science beliefs, (4) the differences between male and female preservice teachers' holding adaptive expertise and reformed science beliefs, (5) how work experience affects preservice teachers' beliefs about reformed science and adaptive expertise skills.

A total of 272 pre-service teachers of the science education department in a public university located in Ankara participated in this study. The study took place during the spring period of 2020 semester both face-to-face and online by using the Adaptive Expertise scale and BARSTL (Beliefs about Reformed Science Teaching and Learning) questionnaire.

The data were analyzed by using factor analysis and MANOVA(Multivariate analysis of variances). The results of the research indicated that the preservice science teachers held a high level of adaptive expertise skills and reformed beliefs in their teaching overall. Specifically, preservice teachers' adaptive expertise skills develop over time emphasizing that senior levels had sophisticated levels of adaptive expertise than freshman, sophomore and junior levels. On the other hand, there was no difference between academic majors of preservice teachers. Likewise, gender and work experience did not affect the adaptive skills and reformed stance of teachers.

Keywords: Adaptive Expertise, Beliefs about Reformed Science Teaching, Level of years, Academic Major, Preservice teachers, Gender, Work experience

ÖZ

FEN ÖĞRETMEN ADAYLARININ UYARLANABİLİR UZMANLIK VE REFORMİST FEN EĞİTİMİ İNANÇLARININ ARAŞTIRILMASI

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Araştırmanın temel amaçları, (1) fen bilgisi öğretmen adaylarının uyarlanabilir uzmanlık düzeyini ve reformist inançlarını, (2) öğretmen adaylarının uyarlanabilir uzmanlıkları ile fen öğretimi ve öğrenimine ilişkin reformist inançları arasındaki akademik branşlar açısından farklarını, (3) uyarlanabilir beceriler ve reform edilmiş fen inançları ile ilgili yıl düzeyleri arasındaki farklarını, (4) erkek ve kadın öğretmen adaylarının uyarlanabilir uzmanlık ve reformist fen bilimlerinin arasındaki farkları, (5) iş deneyiminin öğretmen adaylarının reformist bilim ve uyarlanabilir uzmanlık becerilerine etkisini incelemektir.

Araştırmaya Ankara'da bir devlet üniversitesinde Fen Bilgisi eğitimi anabilim dalında eğitim alan toplam 272 öğretmen adayı katılmıştır. Çalışma, 2020 bahar döneminde hem yüz yüze hem de çevrimiçi olarak Uyarlanabilir Uzmanlık ölçeği ve BARSTL (Reformlu Bilim Öğretimi ve Öğrenmesi ile İlgili İnançlar) anketi kullanılarak gerçekleştirildi.

Veriler, faktör analizi ve MANOVA (Çok değişkenli varyans analizi) kullanılarak analiz edilmiştir. Araştırmanın sonuçları, fen bilgisi öğretmen adaylarının

yüksek düzeyde uyarlanabilir uzmanlık becerilerine sahip olduklarını ve genel olarak öğretimlerinde reform inançlara sahip olduklarını göstermiştir. Özellikle öğretmen adaylarının uyarlanabilir uzmanlık becerileri zamanla gelişerek, dördüncü sınıfların birinci, ikinci ve üçüncü sınıflara göre gelişmiş uyarlanabilir uzmanlık seviyelerine sahip olduğunu vurgulamaktadır. Öte yandan öğretmen adaylarının akademik branşları arasında fark yoktu. Aynı şekilde, cinsiyet ve iş tecrübesi, öğretmenlerin uyum becerilerini ve reform edilmiş duruşunu etkilemedi.

Anahtar Kelimeler: Uyarlanabilir Uzmanlık, Reform Fen Öğretimine İlişkin İnançlar, Sınıf Seviyesi, Akademik Ana Dal, Öğretmen Adayları, Cinsiyet, İş Deneyimi

To my parents

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AE: Adaptive expertise

BARSTL: Beliefs about reformed science teaching and learning

PTs: Pre-service teachers

CHED: Chemistry education

PHED: Physics education

ESE: Elementary science education

MANOVA: Multivariate analysis of variances

df: degree of freedom

AEQ: Adaptive Expertise Questionnaire

FA:Factor Analysis

STEM: Science, technology, engineering and mathematics

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, the technological and educational innovations challenge the previous generation as well as the new generation. We all strive to follow the new changes in our modern life and be adapted to the new situations in a modern society and educational reform. In educational practices there are also new changes every year and new methodologies which come up very quickly. As teachers can face these changes and challenges in their implementation, it is important to deal with uncertain or unpredictable work situations and learn new technological developments and acquire new work tasks. In recent years, the most quickly developed type of educational practice is STEM (Science,Technology,Engineering and Math) and teachers strive to implement it in their practices. If they are concerned about adaptability of the new situation or not, cannot be known until their success of implementation.

The changing curriculum that cannot be overseen in the education system of Turkey can be the main concern of the adaptability of teachers. The major reforms in the science curriculum of Turkey started in 2000 which put an importance on shifting from traditional teacher-centered classrooms to student-centered learning environments (Cansiz & Cansiz, 2019). Since then, there have been several updates to the science curriculum. In 2004, science curriculum made major changes in philosophy of instruction and teacher-student roles, launching constructivist approaches in instruction (Ministry of Education, 2004). The main aim of the change was to bring up learners who are scientific literate. Following the changes in instruction methods, in 2005 science teachers were again exposed to curricular reforms in the content of science topics (Aksit, 2007). As one of the main concerns then was the outcomes of the teaching processes but the main consideration to processes should have been placed on teachers' reactions. Additionally, the readiness of teachers to accept the changes and implement them in classes ought to be considered. Although some teachers could successfully embrace the changes and follow up with the challenges (Crawford, 2000; Luft, Roehrig & Patterson, 2003), other teachers weren't able to develop instructions according to new reforms (Davis, 2002; Yerrick, Parke & Nugent, 1997). When science teachers started to adapt to new reforms, in 2011 there was a considerable change in both elementary and secondary science curriculums emphasizing again constructivist approach and linking key concepts of elementary and secondary science skills and spiral curriculum (MoNE, 2011). Moreover, in 2013 the Ministry of Education (2013) published some minor changes in elementary science education curriculum. The most striking alteration was the starting year of science which was defined as the third year of formal education. Besides technology, creativity and innovativeness, the socio-scientific issues and sustainable development concepts were added (MoNE, 2013). Almost each academic year of instruction, teachers face some changes in their fields and it is expected that teachers handle these situations and complete the outcomes successfully. Within the reforms of science curriculum in Turkey, new methods in science (eg., STEM) emerged and teachers were required to adopt these student-centered and innovative methods to bring up scientific literate citizens. Several studies showed that despite the efforts of curricular reforms in science curriculum, teachers mostly retained their traditional views of science and weren't adaptable enough to the confronted situations (Aikenhead, 2006; Davis, 2002; Jenkins, 2002). Therefore, it is essential for teachers to have a professional development, especially in preservice periods, on how to apply new changes in classrooms and what to teach and use to support their instruction (Loucks-Horsley et al., 1998). Teachers are required to adopt completely different methods and styles in their instruction, they will have to adapt to the changes and challenges of the redesigned curriculum (Aksit, 2007).

The 21st century challenges teachers to be reform-oriented in curriculum, lesson design, assessment and to have teacher expertise in order to effectively and innovatively create a learning environment for students (Rotherham & Willingham, 2009).

Consequently, the shifts of curriculum changes considered the 21st century skills of creativity, innovativeness and technological literacy (Tutkun & Aksoyalp, 2010; Kaufman, 2013). The Partnership for 21st Century Skills (2006) advocated integrating core academic knowledge, critical thinking and multidimensional abilities in teaching and learning processes to help learners succeed in their future career life. Gardner (2007) asserts that the new millennium witnesses the rapid time and vast changes by steadfast advancements in science, technology and globalization. Accordingly, the educational demands of the 21st century require novel and different teaching and learning practices that prepare individuals to adapt to challenging situations and utilize technology to create challenging and novel support (Christenson, 2010; Friedman, 2007; Wagner, 2012). The Council on 21st Century Learning (2008) suggested that teachers should be able to respond to fast changes, show an eagerness to learning and encourage innovation. Thus, it is important for educational institutes to develop skills such as transfer of knowledge, problem solving, communication and self-management in order to cope with uncertain situations of this century (Pellegrino &Hilton, 2012). Under this circumstance, it is essential for higher educational institutions to update the programs to help students advance these skills (Ozturk, 2015).

Another biggest challenge of the 21st century is the outbreak of COVID-19 pandemic, which has changed life in all fields totally. The teachers faced the most thought-provoking periods of education time that led them to reconsider the way of adapting to new situations. As they moved from conventional face-to-face education to online education, teachers were required to use their adaptability skills to ensure the desired outcomes of their teaching. The problem of how teachers are competent enough to struggle with this extraordinary situation and handle using innovative technological means to teach in distant classrooms is of utmost importance for educational settings. Once more again, we have been convinced that complex challenges being faced in the new millennium can be explicated by advanced innovative solutions requiring graduates to be proficient in problem-solving, self-management and adaptability (Bassett, 2005).

Under these circumstances, the most important obstacle in implementing new curriculum, reforms and methods is teacher perception and non-adaptability. Belief, which are the most worthwhile constructs, shape teachers' instructions and influence the way of teaching practices (Coenders, Terlouw & Dijkstra, 2008; Smith & Southerland, 2007). Similarly, beliefs can affect teachers' view of change and adaptability. Because most science teachers believe that teaching the principles of science is more important rather than changing their teaching in any kind of reform (Hansen & Olson, 1996). Beliefs about what it requires to be an expert, affect the way teachers search for what they don't know and take steps to better the situations (Bransford et al., 2004).

Therefore, examining the beliefs of teachers with respect to the reformed movement of science and their consequent adaptive expertise skills will provide paths for developing the necessary skills for 21st century teaching. In the following sections, adaptive expertise and reformed beliefs of teachers will be discussed. Further, the importance of studying these constructs in science education will be emphasized.

1.2 Adaptive Expertise

Expertise is the ability to handle the information speedily and identify the solutions for the problems in particular skill or domain knowledge (Hatano & Oura, 2003). The processes of expertise are without no doubt accumulated through experience which is mostly based on solving problems (Hatano & Inagaki, 1984). The expertise can be gradually developed by the supervision of capable ones turning the individuals to more enriched and integrated ones (Vygotsky, 1978). Emphasizing Piagetian terminology (Piaget, 1950) which states that a new problem is firstly assimilated to pre-existing knowledge and later accommodated to the situation, novices become experts by not only performing the procedural skills but also by comprehending the nature of the skills and problems sufficiently (Hatano & Inagaki, 1984). When we illustrate a person who graduated from university and started working in the workplace, the clear path of how the novice can become an expert or the patterns of becoming an expert can be observed. The first day a person comes to work, the supervisor or the experienced workers will show what to do by giving a procedure to follow. Through observation, feedback and instruction, the individuals acquire knowledge without any difficulties, thus, possessing procedural knowledge rather than conceptual knowledge (Hatano & Inagaki, 1984). Nevertheless, if a person wants to understand, judge and dig deeper into the core of the knowledge, thereby comes up the conceptual understanding of the knowledge. A performer attempts to understand how the world works, invents new approaches towards the situations and predicts explanations to complicated situations which in turn leads to constructing mental models (Gentner & Stevens, 1983). To put it another way, a person can acquire conceptual knowledge by using procedural skills and become flexible and adaptive. Accordingly, Hatano and Inagaki (1986) identified two types of experts such as routine experts and adaptive experts. Routine experts are those who perform the tasks quickly through automation of the procedures without constructing conceptual knowledge, whereas adaptive experts perform procedural skills expeditiously but at the same time they have the ability to invent new paths for solving the problem (Hatano & Inagaki, 1986). Adaptive expertise can be defined as abilities of both being innovative and adaptive while also possessing content knowledge related to domain (Mckenna, 2007).

Development of adaptive expertise in individuals is an important factor, as educating lifelong learners to face complex problems and solve these problems is of prior interest (Peng, 2014). AE involves a variety of cognitive and motivational components that are based on having the higher level of expertise, problem solving in various settings and learning through means of constructivism (Crawford et al., 2005). By measuring this complicated cognitive skill, the broad comprehension of various aspects of curricular and educational practices can be ensured (ASEE, 2018).

Teacher adaptive expertise focuses on enabling teachers to extend their knowledge and skill when instruction difficulties and decision making necessitate more than just applying existing knowledge and procedures (Crawford et al., 2005). As the teaching profession is a highly demanding and high-performance occupation, it requires teachers to make rapid decisions in complex and time-pressured situations (Carter et al., 1987; Cypher & Willower, 1984; McDaniel-Hine & Willower, 1988). Thus, the efficiency of teachers is important in addition to problem-solving skills. AE holds a great promise in enabling teachers to possess adequate skills to solve problems immediately and promote learning with improved instructional practice by being engaged in continuous learning processes (Crawford et al., 2005). The 21st century teachers should be aware that to become and stay effective; they should continuously innovate and change to keep up with a nonstatic millennium.

Thus, the focus of research would be on cognitive and metacognitive processes through which the individuals pass by not just applying what they know, but also extending their knowledge to other more complex fields and struggling to solve problems or situations by using their flexibility and innovativeness. To ensure these skills, the pre-service teachers should at least have positive dispositions towards science learning and teaching. Being an adaptive expert leads to significance of teacher professionalism and encourages teachers to become lifelong learners. As teaching in the 21st century is more complex and challenging because it requires teachers to develop expertise, collegiality and creativity (Donaldson,2011).

1.3 Beliefs About Reformed Science Teaching and Learning

Belief or belief system definitions haven't reached consensus between researchers. Beliefs have been studied in diverse fields but, especially in educational fields when explaining the practices of teaching (Pajares, 1992). The researchers have differentiated knowledge and belief to define beliefs appropriately. Beliefs are based on judgment and evaluation whereas knowledge is based on the objective facts (Pajares, 1992). Belief is defined as “deeply personal, stable, lying beyond individual control or knowledge, and usually unaffected by persuasion.” (Rokeach, 1986, p. 786).

Beliefs that teachers possess are the major factors influencing their teaching activities and becoming lifelong learners. Beliefs which shape teachers’ attitude towards the learning and teaching processes cannot be overridden when we talk about the effectiveness and fruitfulness of the interrelated process of learning and teaching (Levitt, 2001). Thus, teacher beliefs are the key in comprehending and reforming science teaching and learning (Crawford, 2007; Jones & Carter, 2007).

The recent movement in science emphasizes the importance of constructivism. Constructivism in science indicates that knowledge is not a direct transmission from teacher to student but it is active construction in the mind of learners (Driver et al., 1994; NRC, 1996; Harlen, 1999). As constructivism claims; we as learners form our own mental models, maybe altering completely the previous knowledge or building on it the learnt information (Piaget, 1950; Driver et al., 1994; NRC, 1996). Learning science from constructivism is an active process and social aspects of gained experiences are of utmost significance. Reformed movement in science teaching and learning is affected by constructivism movement (NRC, 2000; AAAS, 1993). The reformed science belief is defined as the reform movement which embedded philosophical and theoretical aspects of constructivism advocating that the knowledge is not built by only teachers but, in contrast, constructed by learners (Driver et al., 1994; AAAS, 1993; NRC, 1996). Teachers who are reform oriented have the skills of making students construct their knowledge by inquiry, allowing them to practice by themselves and sharing the ideas together with their peers and value the findings of their peers (NRC, 2000).

Notably, the most crucial attentions in successful implementation of reform movement should be paid to professional development of science teachers and their personal development. Good science teachers should possess some basic inquiry driven skills to make their students ask questions that promote the open-ended answers and make them work together so that they can explain and ask each other questions (NRC, 1996). To do this or to facilitate this learning, science teachers should start the lesson with the question about nature and make learners participate actively, making concentration on the collection and use of evidence and emphasizing not only findings but also knowing (NRC, 1996). Reform-minded ideas see the teacher as an activator or facilitator who is curious and open to new challenges. So the issue that we should consider is teacher beliefs which are the key component of the understanding and reforming science education. Teachers' beliefs about science should be considered as a profound aspect of practicing teaching and implementing their instruction. Consequently, the success of the reform-oriented movement in science depends on the beliefs and practices of teachers (AAAS, 1989; Bybee, 1993; NRC, 1996).

1.4 Why to study AE and Reformed Beliefs in Science Education

In order for science teachers to become reformed in their practices, the need for adaptive skills is the most significant point (Crawford et al., 2005). In the changing world, the innovativeness and ability to be adapted to reforms in science and other fields is the primary necessity for individuals of the 21st century (P21, 2016). It is the education system's responsibility to ensure that students are succeeding as innovative and technologically equipped individuals of the future (Alismail & McGuire, 2015). Consequently, the science teachers' role in this duty is of prior importance. The purposes of science teaching ensures that students develop their research, investigation and critical thinking skills to become lifelong learners (Duruk et al., 2016). Thus, in order to bring up scientific literate and lifelong learners who are keen on learning, science teachers should be innovative and adaptable to reforms by themselves. In this research it is attempted to see the level of the science teachers' readiness to be in the reformed alignment and adaptability, for this purpose there are some reasons to study adaptive expertise and reformed beliefs.

The first reason to study both constructs is to see the cognitive and belief system of preservice teachers. Science teachers' beliefs about reform in science is essential in comprehending and reforming science education because their beliefs about learning and teaching science affect the following patterns in practice (Ozfidan et al., 2017). Similarly, teachers' adaptive expertise, which is a cognitive construct, is the crucial skill as this may influence the integration of innovation and flexibility of instructional practices in the classroom environment (Crawford et al., 2005).

The second reason for studying adaptive expertise and beliefs about reformed science of teachers is to explore the level of teachers' readiness to accept new changes and apply these changes in their practice. Consequently, science teachers' adaptive skills can contribute to providing a successful learning environment for pupils. If teachers are adaptive experts themselves, in designing their instruction they will help students develop types of knowledge representations and ways of thinking which support development of expertise (Goldman et al., 1999).

Lastly, the need to study adaptive expertise and reformed beliefs emerged from the alignment of the new millennium. The 21st century curriculum requires teachers to use more student-centered methods than traditional practices and face the advanced technological developments (Alismail &McGuire, 2015). Particularly, adaptive expert teachers embrace the difficulties with strategic innovativeness, flexibility and problem-solving (Crawford et al., 2005). Hence, it is important for teachers to be aligned with 21st century skills to reform and innovate when confronted with uncertain conditions in curriculum and instruction.

Therefore, in this study the adaptive expertise and reformed science beliefs of preservice teachers will be studied together to see the readiness of candidate teachers when confronted with reforms in science and ability to extend knowledge when instruction demands more than just simply applying existing knowledge.

1.5 Adaptive expertise, Reformed beliefs and Demographic variables

Both adaptive expertise and reformed beliefs research have shown that demographic variables can affect these constructs (Johnson et al., 2015; Fisher & Peterson, 2001; McKenna, 2007; Mylopoulos & Regehr, 2009; Martin et al., 2006; Karaman & Karaman, 2013; Crawford, 2005). Henceforth, similar to previous studies, in our study we have investigated demographic variables in detail.

The various studies on the academic majors of individuals with adaptive expertise skills have indicated that no differences exist (Fisher & Peterson, 2001; Yalvac et al., 2015; Mylopoulos & Regehr, 2009). With the development of the scale, mostly engineering departments were exposed to measure their adaptive skills as engineering required a high level of innovativeness (Fisher & Peterson, 2001). The study of Fisher and Peterson (2001) revealed that there were no significant differences between disciplines of engineering majors. Likewise, for medicine majors the results show the lack of differences between groups (Mylopoulos & Regehr, 2009). When characterizing adaptive expertise in science education fields, there aren't any studies related to major differences, but Crawford et al (2005) studied biology teachers' practices of showing adaptive expert skills. On the other hand, the reformed beliefs of teachers were often studied to see academic major differences of science teachers. Karaman and Karaman (2013) conducted study in a public Turkish university to see the differences of science teachers and elementary teachers and concluded that no significant differences existed in holding reformed beliefs between teachers. When we look at the overall research studies about adaptive skills and reformed beliefs, further studies need to be investigated to see academic major differences of science teachers.

Moreover, the grade level of preservice teachers can be a major factor in affecting the reformed beliefs and adaptive skills. The research on the level of years of students in adaptive expertise yielded that senior engineering students had higher adaptive expertise manifestations than freshman students (Yalvac et al., 2015). However, the years of study didn't show particular differences in medicine majors (Mylopoulos & Regehr, 2009). For the exploration of whether reformed science beliefs were affected by level of years no major findings can be clarified. Consequently, both adaptive expertise and reformed beliefs of teachers should be investigated with respect to their level of years.

In addition to grade levels, work experience of individuals ought to be explored. Although empirical studies demonstrated that teacher beliefs are "stable" and "resistant to change" (Kagan, 1992), an influential role of professional development can help teachers to align their beliefs with reform efforts (Sampson et al., 2013). Similarly, the workplace learning experiences which include both knowledge and innovation can increase the level of adaptive expertise in fields of interest (Martin et al., 2006). The experienced individuals had higher adaptive expert skills rather than inexperienced ones

(Yalvac et al., 2015). Hence, the influence of teaching experience on adaptive skills and reformed beliefs must be examined.

Finally, the effect of gender on reformed beliefs and adaptive expertise of science teachers can be studied in detail. Specifically, the adaptive skills of teachers in terms of their gender differences could be explored as there are no evident results between male and female participants. On the other hand, the research conducted in reformed beliefs of science teachers revealed that male prospective teachers hold reformed beliefs, but female counterparts hold more traditional views regarding reform movement (Karaman & Karaman, 2013). After all it isn't always the case in the gender factor, some studies have shown that teacher's gender hadn't influenced their beliefs to reform (Levitt, 2001; Sampson et al., 2013).

To conclude, it is of necessity to analyse demographic variables of science teachers on their respective adaptive skills and reformed beliefs in order to have a full portrait of the needed education for each group.

1.6 Significance of the study

In the modern and technologically advanced life, individuals need to proceed in their workplace and should enable themselves with lifelong learning. Especially, the teachers are required to have a high sense of adaptation as they face the most difficult tasks like change in curriculum, the new developments in the field of methods and technological advances. The main focus here should be placed on the problem-solving skills of teachers to deal with the everyday problems that they can face, solving the problem not only applying the basic knowledge but using the innovative skills and extending their knowledge by analyzing and synthesizing (Crawford et al., 2005). Teachers' flexibility and practice of the methods and innovations depend on how they perceive their profession and what it is meant to be a teacher in science education, which continuously develops and challenges society. The metacognitive skills and the epistemological stance of prospective teachers can actually shape their adaptability. Will teachers adopt reformed curriculum or methods effectively in classes and overcome difficulties coming up with the new century demands depend mostly on their stance about science teaching. Consequently, finding out and comprehending the beliefs and adaptive skills of teachers is critical to the process of educational reform. This research of both adaptive expertise and reformed beliefs construct will be studied for the first time in the science education field and the results of the research may contribute to the departments of science education faculties to improve courses which will engage in development of adaptive expert and reformed science teachers.

1.7 Purpose of the study

Determining pre-service teachers' beliefs about reformed science education and adaptive expertise with respect to their class, departments and gender are among the main aims of the study. In line with these purposes, the research results will determine how much future science teachers can adapt to new conditions and how these abilities of those who have a reformist belief are affected. It requires today's teachers to be teachers who can adapt to the changing world and science fields rather than classical education. Therefore, the first aim of the study is to investigate pre-service teachers' levels of adaptive expertise skills and reformed beliefs by using the Adaptive expertise scale and BARSTL (Beliefs about Reformed Science Teaching and Learning) questionnaire. The second aim of the research is to explore the differences of adaptive expertise and reformed beliefs levels of prospective teachers regarding their grade level, major, gender and professional work experience as it may differ or not according to these characteristics.

1.8 Research questions

The purpose of the study is to investigate the differences between academic major, grade level, gender and work experience of undergraduate science education department students by using the Likert scale of Adaptive Expertise instrument and BARSTL (Beliefs about Reformed Science Teaching and Learning) questionnaire. The research questions for the study are as follows;

1. What is the level of adaptive expertise and reformed beliefs of science preservice teachers?
2. Do preservice elementary science teachers, chemistry teachers and physics teachers differ in terms of adaptive expertise and reformist beliefs?
3. Is there a difference between preservice teachers' level of years regarding their adaptive expertise skills and reformist beliefs? Are senior level students more adaptive and reform-oriented in their teaching?
4. Do males and females differ in terms of overall adaptive expertise and reformed beliefs in science education?
5. What is the impact of preservice teachers` professional work experience on adaptive expertise and reformist beliefs?

1.9 Definitions of the terms

Expertise: Expertise is defined as the ability of processing information quickly and having efficient domain knowledge to deal with the problems (Hatano & Inagaki, 1986).

Adaptive expertise : Adaptive expertise is defined as the construct which involves a variety of cognitive and motivational components that base on having the higher level of expertise, problem solving in various settings and learning through means of constructivism (Crawford et al., 2005). According to Mckenna (2007) adaptive expertise can be defined as abilities of both being innovative and adaptive while also possessing content knowledge related to domain.

Routine expertise: Routine expertise can be defined as the ability to perform a task quickly and accurately, without building conceptual knowledge (Hatano & Inagaki, 1986).

Belief: Belief is defined as “deeply personal, stable, lies beyond individual control or knowledge, and are usually unaffected by persuasion.” (Rokeach, 1986, p. 786).

Reformed belief: reformed science belief is defined as the reform movement which embedded philosophical and theoretical aspects of constructivism advocating that the knowledge is not built by only teachers but, in contrast, constructed by learners (Driver et al.,1994; NRC, 1996).

Constructivism: According to constructivism, knowledge is not a direct transmission from teacher to student but it is constructed in an active way in the mind of learners (Driver et al., 1994; NRC, 1996; Harlen, 1999).

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the literature review of adaptive expertise and reformed beliefs about science teaching and learning. Adaptive expertise review will cover: expertise, adaptive and routine expertise and application of adaptive in education particularly in science education and adaptive teaching. Reformed beliefs section will include review about beliefs, teachers' beliefs and reformed beliefs which is discussed in four subdimensions.

2.1 Expertise

When we start thinking about adaptive skills, first there should be considered who experts and novices are. The main difference between them is that of performance. Experts are careful in finding the details and they tend to make the patterns more meaningful; they can recall the information easily not spending a lot of efforts, they are skillful in the routine and automotive accomplishments leading to high speed and efficiency in their work; experts have valuable, composite domain-specific information which were built from the longitudinal experience in hierarchically integrated way (Bransford et al., 2000, Chi, Glaser, & Farr, 1988). Expertise can be defined as a skill of processing information quickly and finding out coordinated solutions to problems, consequently working out problems in a certain domain (Hatano & Inagaki, 1986). In other words, expertise is based on accretion of practice and ability to figure out more difficult problems in their fields by using the enriched prior knowledge. Experts are not only good at accomplishing the tasks accurately but they also possess essential skills to move it further. When characterizing someone, who possesses expertise skills, we can emphasize some main characteristics that are of utmost importance. Being an expert requires competency in the domain and faster performance on tasks rather than their counterparts (Chi, Glaser, & Farr, 1988). Moreover, experts are outstanding in long term and short term memories and they can solve a problem on a deeper level. Unlike novices, who try to solve the problem at once, experts dig deeply into the problem (Chi et al., 1988). Last but not least characteristic of experts is that it helps individuals to self-monitor their understanding (Chi et al., 1988).

The ability of self-regulation empowers experts to apply procedures at the right time and make accurate predictions about outcomes (Hatano & Inagaki, 1986). Above all, expertise provides the ability to deal effectively with unfamiliar situations and problems (Carbonell et al, 2014). However, the experts' distinctiveness doesn't make them highly adaptive and it cannot be inferred that they can apply every type of skill to their problem solving. Then comes to mind the routine and adaptive expertise. While some experts concentrate on applying knowledge and procedures to address new cases and solve problems, other experts are more disposed to use new cases or problem as chance to learn and extent their knowledge (Bereiter & Scardemalia, 1993; Hatano & Inagaki, 1986; Schwartz, Bransford, & Sears, 2005).

Expertise development can occur from shifting novice thinking to expert practices. Initially learners may be novices in the particular fields, then by cognitive apprenticeship and practice of the discipline, they are able to move from novices to experts (Cobb, 1994; Collins et al., 1989; Driver et al., 1994; Rogoff, 1990). This process embodies guided participation by the expert of the field and transferring responsibility to novice gradually (Rogoff, 1990). Likewise, Vygotsky`s "zone of proximal development (ZPD)" supports novices to become experts by scaffolding and interaction with more capable ones (Vygotsky, 1978). The ZPD is the distance between individuals' actual and potential development. By interacting with adults or more competent pupils, children can perform at their potential levels (Vygotsky, 1962; Wood, Bruner & Ross, 1976). Consequently, individuals learn strategies, think on their own and generalize knowledge. Rogoff (1990) stated that learners adopt thinking patterns that were reflected by adults or knowledgeable ones by internalizing the scaffolded actions. Eventually, scaffolds are needed to aid individuals to become more expert in their field (Goldman et al., 1999).

2.2 Adaptive expertise and Routine expertise

Hatano and Inagaki (1986) have moved the term of expertise to a higher level by making distinctions between “routine” and “adaptive” expertise. Adaptive experts are those who possess efficient procedural skills and understanding of meaning and deep nature of source. In contrast, routine experts have capability of learning faster without formulating conceptual knowledge (Brophy, Hodge & Bransford, 2004). Beyond characterizing the distinctions between adaptive and routine expertise, researchers have featured reasoning and problem-solving processes that allow adaptive experts to continue to learn. One example of such a process is theory-building or explanation-testing (Bereiter & Scardamalia, 1993; Gott et al., 1992; Hatano & Inagaki, 1986). Individuals learn to perform a task or a problem faster and accurately and how they were instructed with the procedure, but they lack upgrading or improving the conceptual knowledge they possess (Hatano & Inagaki,1984). When we think about our daily chores we perform, we don’t pay much attention to how some things work but we overlook details and neglect the nature of things. For instance, cooking is a typical housework most of us do when in the kitchen and when doing this action we have a memorised recipe in our mind which helps us to perform the action. It is a repeated and an automated action that uses basic skills and procedure. When time passes, we become quite skillful at it. Besides, we are successful only if we have the same objects and materials that lead us to become routine experts rather than adaptive (Hatano & Inagaki,1984). Routine experts are remarkable in speed, accuracy and automation of actions but they don’t possess flexibility and adaptiveness (Hatano & Inagaki,1984). Rumelhart (1979) states that “a procedural skill is often efficient but only for a limited type of problem, mainly because the information embedded in the skill cannot be easily recombined to form other procedural skills” (p.14).

Various studies across adaptive expertise have given some precise description of what is different between these terms and there some features which make it clear. Under this description it is clearly seen that routine qualities are actually subsets of adaptiveness which is illustrated in Figure 1. Firstly, adaptive experts necessitate all main components of routine expertise such as being an expert and having efficient skills (Fisher & Peterson, 2001). This implies that adaptiveness develops from the routine expertise components, however there is more way to achieve adaptiveness. Moreover, adaptive experts have more developed metacognition skills rather than routine ones (Crawford et al., 2005). Furthermore, adaptive expertise deals with flexibility, continuous need to learn and innovate and facing the challenges openly (Barnett & Koslowski, 2002). At this point, the distinction is seen clearly between routine and adaptive experts, because both of them actually possess similar core concepts but routine ones cease their learning and don't develop to the level of adaptiveness (Chi, 2011).

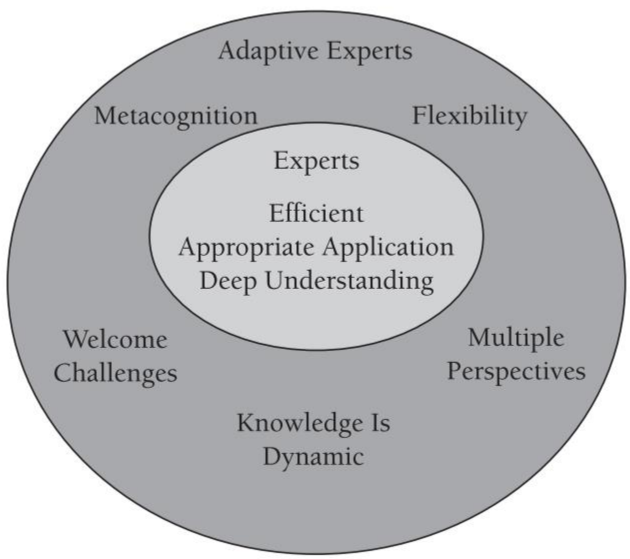

Figure 2.1 . Routine versus adaptive expertise (Martin et al., 2006)

Individuals who are routine experts are concerned with the nature of the object when there is a desirable outcome and if the object contains randomness rather than invention of new procedures. On the other hand, adaptive experts deal with highly standardized and non-random skills. Moreover, routine experts are less likely to take risks relying on more conventional versions whereas adaptive ones are willing to engage in challenging experimentations. Lastly, routine expertise is mostly based on not examining new variation and not providing answers to the question why. In contrast to routine adaptive expertise based on understanding the action and encouraging to find the reasons for the act (Hatano & Inagaki,1984). To sum up, routine experts have the capacity of problem solving different from ordinary people and can produce some consequences of knowledge not with the understanding but with the well-established methods.

2.3 Adaptive expertise and its aspects

Nowadays workplaces and work environments are in need of staff who can deal with new technological innovations and upcoming uncertainties. 21st century job requirements are characterized by increasing complexities and higher level of knowledge and task volatility (Molloy & Noe, 2009). Employees want their employers to adapt to changes in their domain and to be flexible in order to deal with novel situations effectively (van der Heijden, 2002). Hatano and Inagaki (1986) point out that some individuals can master changes and come up with new ways and use their expert skills but somehow the other ones, who don't possess required skills, can`t catch up with newness. The latter ones lack the ability of adaptiveness. Adaptive expertise is defined as the capability to perform innovative and adaptive to novel changes and challenges at the same time having efficient subject knowledge (Mckenna, 2007). Adaptive experts are efficient in problem solving and have deep content knowledge that is contextualized in their field of study. They learn throughout their career and always want to find opportunities to improve themselves (Fisher & Peterson, 2001). Finding various approaches to problems and observing their progress in areas of study are the main concerns for adaptive experts (Hatano and Inagaki, 1986; Wineburg, 1998). Another key point Hatano (1982) expressed about adaptive expertise is that due to conceptual understanding of knowledge it leads to invention of procedures in case of failure of existing ones.

How can adaptive expertise skills be developed? What is the rationale for developing the necessary skills so that individuals become adaptive experts? Not only efficient knowledge but also creation of new solutions is necessary in the path of success. There can be situations which they have never witnessed before and in these cases the process of innovating practice takes place. At the same time complementary efficiency also makes up the dimensions of adaptive expertise. Adaptive expertise serves as the balance between efficiency and innovation for figuring out problems. To put it differently, adaptive expertise is the product of acquired skills and encouragement of training (Mylopoulos & Regehr,2009). Henceforth researchers were dealing with how adaptive expertise can be instilled in students throughout their education life. Schwartz, Bransford and Sears (2005) stated that to promote adaptive expertise it is of utmost importance that students have a chance to be innovative and develop efficiency attributes of application. Through learning new knowledge and applying it to different occasional states by digging out new approaches and paths, can students learn to be adaptive experts? Figure 2 shows that if a novice is supposed to engage in both activities that promote knowledge and innovation, it is possible to achieve the state of adaptiveness (Martin et al., 2006).

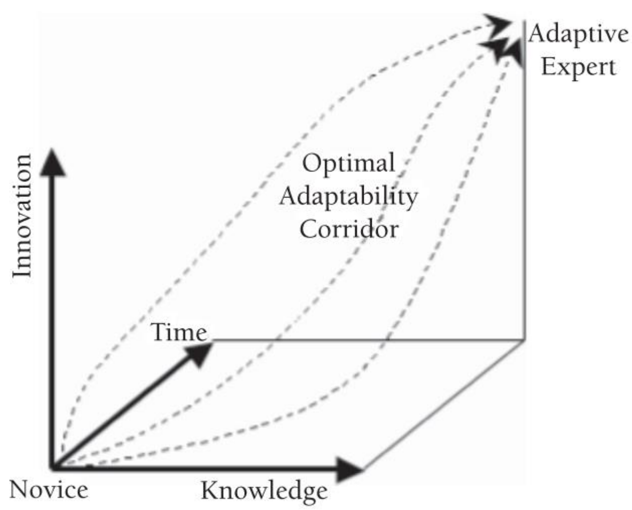

Figure 2.2 Developmental trajectory for Adaptive Expertise (Schwartz, Bransford & Sears,2005)

Having efficient knowledge and being able to innovate on certain tasks in the meantime can lead to bringing out adaptive expertise. As it can be seen in Figure 2, there is an Optimal Adaptability Corridor (OAC) which points out the development of innovation and efficiency together (Mckenna et al., 2006). When time passes novices who experience the balanced entity of innovation and knowledge can achieve the state of adaptive expertness. It is of utmost importance using balanced form of these components to prepare educational design and instruction (Mckenna et al., 2006). OAC pictures effective and appropriate framework for further instructional methods to imply adaptive expertise in individuals.

When we look deeply at the nature of adaptiveness, adaptive expertise skills are mostly related to metacognitive and cognitive skills which are related to constructivist approach thus including the flexibility, innovativeness, continuous learning, challenges and creativity. Fisher and Peterson have identified four basic aspects of adaptive expertise: metacognition, multiple perspectives, goals and beliefs and epistemology. These aspects are going to be discussed in detail in the following parts of adaptive expertise review.

Metacognition. Metacognition aspect of adaptiveness indicates individuals monitoring problem solving, their weak sides and avoiding simple interpretation of a problem (Pellegrino & Hilton, 2012). People with metacognitive skills can self-assess themselves and keep the track of their performance. They don't overlook their failure or success but rather think about what caused it and how it should be diminished or enriched. Likewise, they can recognise their areas of incompleteness (Fisher & Peterson,2001). These types of recognition don't make them weaker, besides it makes individuals build up their confidence and move on further by facing the most challenging situations bravely.

Multiple perspectives. Multiple perspectives represent the capability of using various methods to solve problems (Hatano & Inagaki, 1986). Not only focusing on traditional approaches but also applying more innovative and complex solutions to problems. Correspondingly, the ones who have multiple perspectives abilities embrace new knowledge with enthusiasm and apply this information to situations where creativity is needed (Fisher & Peterson, 2001). In the light of creativity, they can act flexibly towards new challenges which is also the most important key in becoming adaptive (Brophy, Hodge & Bransford, 2004).

Goals and beliefs. Individuals' goals and beliefs shape their concern about learning. Self-conceptions of individuals are nurtured by goals which in the way shape their belief and value in terms of learning (Dweck & Legget,1988). As a part of adaptive expertise, self-regulation assists in identifying goals to bring forth ideas and better the existent ones (Mckenna, 2007). Self-regulated learners use specified schemes to attain academic goals by setting certain goals and monitoring the progress throughout their performance (Zimmerman, 1989). For one thing, they have purposeful goals and work hard to achieve. To point out, opportunity to grow and ability to proceed in the face of difficulties and uncertainties are the biggest attainable challenges for students with goals and beliefs (Fisher & Peterson, 2001).

Epistemology. Epistemology is a metacognitive process concerning one's beliefs about the knowledge and stance towards the nature of knowledge and its generation (Hofer, 2004). The epistemological feature generates that knowledge has an evolving or dynamic nature and enables learners to practice knowledge continually (Fisher & Peterson, 2001). Personal epistemology has emerged from cognitive developmental theories of Piaget(1950) and since it studies intellectual development of students. Hofer (2004) states that knowledge is built by the learner hence contributing a balance between subjective and objective views of learning which regards knowledge as continuously evolving and justifiable. From a philosophical view, epistemology pertains to origin, nature, limits and methods of human knowledge (Hofer, 2004).

2.4 Application of adaptive expertise

The ability to innovate and apply new knowledge is of utmost importance in many fields of work . The study that was conducted in the field of adaptive skills can state the rationale for further need in other areas. The initial studies in this field started in engineering departments and the conclusion drawn from the study specified that the engineers have high adaptive skills (Peng et al, 2014). There are examples in medicine fields of work too. This is considered to be of paramount importance to researchers as it requires development and incorporation of new knowledge in its daily practice (Mylopoulos & Regehr, 2009). The study conducted in medicine education revealed interesting results stressing that students of third and fourth years didn't exert on being innovative and stating that innovativeness is out of their scope (Mylopoulos & Regehr, 2009). Notwithstanding medical students' ability to innovate, most of them consider that having efficient knowledge about the field is adequate for their success (Mylopoulos & Regehr, 2009). Engineering and medicine are given as examples to see where adaptive expertise mostly applied to. However, the prior concern in this part is to indicate the research areas in the field of education mostly.

2.4.1 Adaptive expertise in education

The preparation of teachers is a long and complicated process and it has always been a criticism of education. The quality of teachers has prompted to get certification and measurement of the effectiveness (Antony, Hunter & Hunter, 2015). But is it adequate having only prior knowledge? What is necessary and possible beyond knowledge and skill sets? Teachers ought to have some skills beyond basic skills to deal with upcoming difficulties or new changes. At the top of these skills comes the adaptive expertise skill and it has been emphasized as an element of high quality teaching (Cochran-Smith & Feimen-Nemser, 2008; Hatano & Oura, 2003; Sawyer, 2006). Teachers who possess this skill can come up with challenges and become more creative in their classrooms. In nowadays classrooms, teaching expertise requires an accomplished level of different content and pedagogical knowledge related to teacher and student embodiment and sociocultural context of the classroom (Antony, Hunter & Hunter ,2015). Expertise is not directly related to experience of teachers, rather it is about the component of professionalism. As it was stated above the distinctions between routine and adaptive expertise, routines are more apt to use the core skills with fluency, however adaptive experts tend to include the innovations and creativity in their works. Indicating adaptive expertise, they follow the awareness of why and under which circumstances some approaches should be employed or new approaches should be designed. Depicted by the flexibility, innovativeness and creativity, adaptive expertise can be regarded as a psycho-social construct which embodies dimensions of curiosity, control and confidence (Savickas, 2005). Adaptive teachers driven by these constructs, design their classes in the inquiry form engaging students in class and supporting their well-being.

In the teacher education system, adaptive teaching expertise is a “worthy” goal (Hammerness, Darling-Hammond & Bransford, 2005). Within teacher education, the routine expertise is linked with “practice makes perfect” foundation (Aitken et al., 2013; Darling-Hammond, 2014) however, McDonald et al (2014) stated that adaptive teaching isn’t only about practice but also about innovation in practice content, curriculum and teacher pedagogy. Thus, the primary goal of teacher preparation programs is based on giving emphasis on shift from routine to adaptive experts (Timperley, 2013). Thus, to promote the development of adaptive skills, actually, the routine skills play the prior role. The framework that emphasized the shift from routine to adaptive context was proposed by Timperley (2013), two shifts were fundamentally necessary for teachers to achieve adaptability. The first shift concerns shift from self to students, focusing on self as a learner to an effective learning class environment. The second shift refers to teachers' understanding of teaching, viewing teaching as a communicative and sharing relationship with learners. In the study of Antony et al (2015), the main focus was placed on prospective teachers’ acquisition of adaptivity and the process of the shifting from routine to adaptive skills. The program of learning applied a cyclical teaching-as-inquiry process of Timperley (2007) for support of the development of prospective teachers’ professional adaptive skills through theories, practices and how their students learn and respond. In Figure 3, we can see the cyclical process of inquiry which leads to having adaptive skills at the end or hopes of achieving these skills. In this cyclical process, teachers are required to learn students’ learning needs and learning needs of themselves. Then, accordingly teachers are supposed to design lessons and practice it at school teaching. Later they should reflect on their action and cycle draws to their initial point to reconsider their impact on actions.

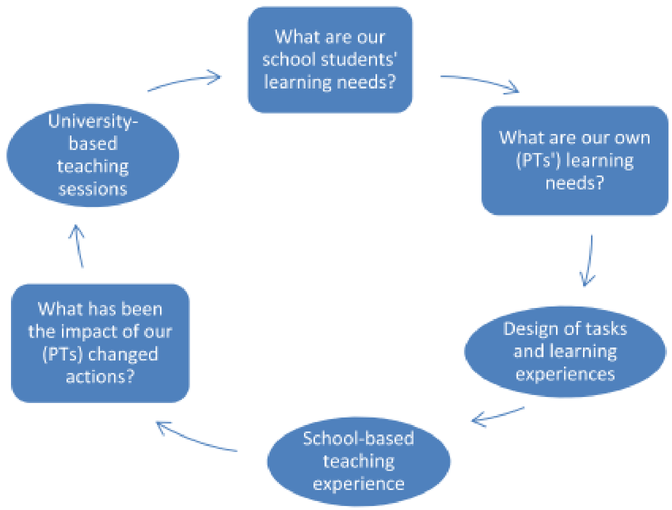

Figure 2.3 Inquiry and knowledge-building cycle (Timperley et al., 2007)

In the study of Antony et al (2015), to show the shift of prospective mathematics teachers from routine to adaptive side, two prospective teachers were chosen as participants of their study. Pip and Troy, who are prospective teachers, differed in their marks from the method courses, Pip received ‘C’ and Troy had ‘A’ from the course. The study was conducted in a qualitative approach and teachers were telling the cases. They both had little experience of teaching and study suggested them to be involved in the teaching process. Pip was worried about her pedagogical knowledge but time passed and she could move from self to more productive learning goals for students like creating the positive environment of learning and teaching. Then the shift occurred to understanding the learning and teaching like forming discussion groups and facilitating the inquiry. By taking action to experiments and sometimes changing the flow of the instruction shows her beginning development of adaptive expertise. Moreover, the same procedures applied to Troy and he also followed the same path and applied the cyclical process. At the end he was observed to show the beginning stage of the adaptive skill. Consequently, training activities that can stimulate individuals to experiment, to make mistakes and to test different solutions can create a flexible knowledge base with adaptive expertise (Carbonell et al., 2014).

Thus, the concept of adaptive expertise sustains the promise of understanding the professional development of teachers and how to endorse development of expertise in practice (Crawford et al., 2005). The findings in the field of education about adaptive skills show the tremendous place which should be emphasized in terms of adaptability. The notion of adaptive expertise in education assists in enabling teachers to continuously learn from their experience, through practice and improve their instructional practices by helping students think critically and analyse procedures (Crawford et al., 2005). Even if some think that they are adaptable enough to situations it is not about accustoming to a particular place, it is about rethinking the current situation and modifying some cases which are trivial, creating more innovative classes and becoming adapted to renewals leading to lifelong learning. The teaching career is no longer static but it is a dynamic course because tools, practices, methods, domain content and learners' characteristics are changing, subsequently teachers should learn unceasingly in order to deal with a rapidly changing environment (Crawford et al., 2005).

2.4.2 Adaptive expertise in science education

We have discussed above that the distinguishing characteristic of adaptive expertise lies in its ability to solve unfamiliar and atypical problems by inventing new procedures. This innovative application tends to show enrichment and refinement of knowledge structures and support continuing experience from which individuals can learn more about problem solving. These skills are mostly required for teachers of science education, who need to possess these skills as the new developments in science or methods of how to teach science are growing and expanding the various contexts of the application. Argumentation method for example was actually in the field of education for many years but the immediate revelation of method challenges most science teachers or

STEM education which is the most innovative of all methods puts teachers in a position of difficulty in integrating into lessons.

STEM education developed from government policy especially from the National Science Foundation integrating science, technology, engineering and mathematics and emphasizing interdisciplinary learning (NSF, 2012). STEM requires teachers and learners to be in alignment with innovation in the 21st century. In regard to 21st century skills such as possessing creativity, innovation, critical thinking and cooperation (Partnership for 21st century learning, 2015), STEM instruction provides an interdisciplinary path to teachers in order to bring up learners capable of adapting to the modern century. The main purpose of STEM education is the progression in economy and education of creative citizens by creating the leading country with scientists and engineers (Danish Technological Institute (DTI), 2015; The President's Council of Advisors on Science and Technology (PCAST), 2012). As a consequence, STEM education became an important part of national education systems in order to bring up students who are productive, well-equipped with 21st skills and creative (DTI, 2015; PCAST, 2012). However, the difficulty of integrating STEM education evolves from the four important disciplines that it includes. STEM education has focused on science, mathematics, engineering and technology (Bybee, 2010). The last two components may pose difficulty for teachers to integrate in their lesson as they should come up with learning and searching for new situations. Therefore, if teachers are adaptive enough, they can deal with novel situations by integrating their conceptual knowledge and new perspectives.

Thus, we can see that science education can expose teachers to different difficult and challenging situations. The necessary education of adaptiveness is of prior concern in the science education field, too. As an illustration of the significance of adaptive expertise in science education, Crawford et al`s (2005) research in the field of education was conducted with Biology teachers using qualitative design. In the study, in-service teachers were asked to construct the laboratory design and by using them answer some complicated questions. Researchers have prepared the tasks that were not only the application of basic knowledge but the ones which required the innovative skills

(Crawford et al, 2005). The conclusions of the study of 20 teachers have indicated that not all teachers possess the necessary skills and they should be supported to deal with some complex problems. Hence, we see that there is a necessity in the formulation of adaptive skills during the pre-service period. These statements lead us to further research in the area of adaptive skills in all major pre-service science teachers by using quantitative methods and suggesting some solutions to improve these skills. In the following section, the adaptive teaching expertise is going to be discussed and point out the necessity of adaptive teaching.

2.5 Adaptive teaching expertise

The predictions of teacher education policy should be based on understanding of pedagogical relations as dependent, responsive and adaptive throughout the teaching career (Griffiths, 2013). The career-long education and teacher professionalism are main components of reflective, accomplished and enquired teachers who have capacity to meet the complexities in their field (Donaldson, 2011). Donaldson (2011) clarified his point of view about teacher education as follows:

> *Some see teaching as a relatively simple task that depends heavily on techniques, subject knowledge and personality ……. but twenty-first-century education is far more complex and challenging and requires the highest standards of professional accomplishments and commitment. Teacher education must ……… develop expertise, scholarship, collegiality and creativity (p. 5).*

Notably, we can see the demand of 21st century education policy is adaptiveness, creativity and innovativeness. In order to achieve high standards of teaching, future educators should place emphasis on new abilities.

Fairbanks et al (2010) observed that to prepare thoughtfully adaptive teachers, who are responsive to students and situations, knowledge addressed in courses aren't sufficient and there should be more beyond giving only knowledge. As Shulman (2004) said even after lots of years of teaching, teaching remains the most challenging, demanding and complex activity. Dealing with a lot of constraints and facing dilemma-ridden situations is what makes teaching demanding (Fairbanks et al., 2010). Characteristics of successful teachers include seeing every situation differently, applying multiple perspectives and possibilities and employing professional knowledge differently (Duffy, 2002; Bransford et al., 2005). Although teacher candidates learn knowledge of effective practice, learning theory and instructional strategies, not all candidates are capable of implementing techniques in their teaching (Fairbanks et al., 2010). Thus, teacher candidates should be encouraged with the opportunity to engage both in the process of knowing and the process of developing oneself as self-conscious to deal with highly complex and highly standardized situations in the classroom. Thoughtful adaptive expert teachers do not only have efficient declarative and procedural knowledge but they also possess skills which allows them *"when"*, *"how"* and *"what"* to apply at certain times. When confronted with difficulties or newness, they seek for multiple perspectives and anticipate for multiple possibilities (Fairbanks et al., 2010). Consequently, adaptive teaching expertise is identified as an important constituent of high-quality teaching (Hatano & Oura, 2003). Developing adaptive expert teachers who can mirror and renovate their actions and get feedback from their practice (Bransford & Schwartz, 1999) should be the main goal of the teacher training system. To put it differently, adaptive teachers will have a huge contribution to the education system. Important to realize that adaptive teachers enrol in self-assessing processes and decision-making strategies which help them to smoothly move away from planned schedules, when facing unfamiliar questions, and recognize needs of students so that lessons can be refined or changed accordingly (Soslau, 2012).

Real classroom environments don't feature well-defined, stable and shared goals between teachers and students (Lin, Schwartz & Hatano, 2005). There are a lot of new challenges and difficulties every day. Henceforth, teachers must learn from their experience every single day and adapt to a diverse classroom environment thinking deeply about decisions, noticing pupils` needs and making necessary alterations if needed (Soslau, 2012). For this reason, teachers should be in a pursuit of lifelong learning to improve themselves. Becoming adaptive experts make them question and detect novel problems (Lin et al.,2005), prepare for future learning by formulating and evaluating instruction (Bransford & Schwartz, 1999) , develop self-regulation strategies (Darling-Hammond & Bransford, 2005) and advance professional discourse by applying techniques to different groups strategically (Rogoff, 2003).

Developing adaptive expertise in teachers is seldom mentioned in the field of research but at the same time important (Cochran-Smith & Feiman-Nemser, 2008). The 21st century standards require teachers to be more flexible and adaptive to new technical innovations. Adaptive expertise skills can be emerged by guidance of experts who can help involve in highly complex and deeply contextualized learning procedures. This procedure implies ways of articulating, rationalizing and justifying decision making and adapting to the needs of students (Soslau, 2012). Currently, educators focus on how to prepare teachers to face challenges in the classroom and improve academic achievements (Ball & Hill, 2008; Grossman, 2008). But shifting from just evaluating candidate teacher's behaviour to other aspects of teacher quality to make student teachers learn from their teaching is an emergent need (Hiebert et al., 2007). Thus, teacher educators must motivate teacher candidates to self-assess and self-reform their behaviour (Blacker, 2007; Liston & Zeichner, 1991). With the help of these strategies future teachers may be involved in the process of giving right decisions when needed. Promoting instant and effective solutions to problems is significant in the education system. In 2020, we have witnessed the COVID-19 pandemic which caused the education system to shift from face-to-face to an online system. This condition made us realize that the education system as well as other fields should have the capacity to evolve and adapt to novel situations. As Cochran-Smith and Feimen-Nemser (2008) have emphasized not only demographics and classrooms change, but also social knowledge, technical knowledge and natural world change so as a result teachers must adapt to the new world. Under this circumstance development of adaptive expert teachers for future should be part of teacher training programs.

2.6 Beliefs

Beliefs have been explored in many fields and have been in a central place of importance. Philosophers, social psychologists and anthropologists have been exploring the term “belief” for many years (Richardson, 1996). Although there is no universally consented definition of belief, research from various fields have tried to define the term in their interpretation. But the most considerable agreement between research about beliefs was defining it as psychological understanding or propositions about the world which are supposed to be true (Richardson, 1996).

As beliefs have been studied for long periods and seldom clearly defined, the distinction between belief and knowledge made researchers comment on terms of belief more considerably. Notably, beliefs are established on evaluation and judgement and knowledge is established on objective facts (Pajares, 1992). By this statement he meant that knowledge has epistemological bonds that beliefs lack of. Furthermore, Green (1971) drew attention to distinction between belief and knowledge emphasizing that the former is propositions accepted true by individuals, the latter is concerned with epistemic warrant. Abelson (1979) defined beliefs as a manipulation of people’s knowledge for a specific act. Whereas Brown and Cooney (1982) indicated that dispositions to actions are explained by beliefs. Moreover, beliefs are defined as “mental constructions of experience” which are integrated into concepts (Sigel, 1985). Another definition of belief comes from Harvey (1986) as a person’s depiction of reality which in terms guide the behaviour. The most compelling belief description of Rokeach (1968) states:

> *Beliefs are any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase, ‘I believe that……’(p.10).*

He argued that beliefs have cognitive components of knowledge as well as affective constituents of emotion and behavioural components of actions. Some beliefs are more central than other beliefs and these beliefs are resistant to change (Rokeach, 1968).

The philosophical and psychological stance of belief made it significant in the field of education. Education programs, in particular teacher training programs, come up with the importance of teacher beliefs. As Rokeach (1968) expressed, beliefs can't be observed directly, but can be inferred from what one does and says. In the education of teachers; we cannot directly see their beliefs but by observing what they think about particular methods or how they approach constructivist reforms, some clues about their prior beliefs of teaching and learning can be derived. Hence, beliefs are instrumental in describing a task and choosing a tool which plan or make decisions playing a critical role in defining behaviour (Abelson, 1979; Bandura, 1986; Nespor, 1987; Nisbett & Ross, 1980). Consequently, teachers' beliefs powerfully influence their behaviour (Kitchener, 1986; Lewis, 1990; Tabachnick & Zeichner, 1984). The next part of this review bases on the teacher' beliefs in detail.

2.7 Teachers' beliefs

For many decades teachers' beliefs have become prior research topics in the education field. It has been affected by the goal of education which is directed by the teachers' beliefs. Richardson (2003) points out that teacher education systems are important both in philosophical and psychological view. For the philosophical part it is considered to change a teacher's beliefs, as for the psychological part preservice teacher' s central beliefs about teaching makes it guide their following actions. Consequently, teacher training programs struggle to alter the traditional beliefs to more constructivist beliefs. However, what causes teachers' beliefs to be more traditional or how teachers come up with their prior beliefs?

All teachers hold some sort of beliefs about teaching and learning before practicing in the classroom or after practicing. These beliefs can be cause-effect propositions from many sources, personal experience generalizations or beliefs and values (Clark, 1988). When entering education faculties teacher candidates almost have beliefs constructed from personal practice or cultural beliefs, some can be very long standing (Bruner, 1996; Holt-Reynolds, 1992). These earlier beliefs and knowledge influence the way teachers formulate the following learning of new knowledge (Scheurman, 1996). Kagan (1992) defined teacher beliefs as implicit and unconscious presumptions had by teachers about students, classroom and material to be used. Another view on beliefs of teachers have come to light from Tabachnick and Zeichner (1984), who used 'teacher perspectives' instead of teacher beliefs and defined it as reflective and socially determined inferences that lead to consequent actions including beliefs, intentions, interpretations and behaviours altogether.

Richardson (1996) identified three major sources of teacher beliefs; personal experience, schooling experience and formal knowledge experience. She put an important place on schooling and instruction experience due to students' prior experience in the nature of teaching and learning in their school. Thus, prospective teachers' pre-existing beliefs as students, not as teachers, have a particular effect on formulating prior beliefs of teachers. Likewise, Nespor (1987) remarked that teacher beliefs derive from memories of specific events. Consequently, it is of utmost importance to investigate student teachers' beliefs and attempt to move them from traditional to more constructivist. But at the same time beliefs of teachers are so delicate fields of study that can flourish or go to pieces if not handled with care. Kagan (1992) stated that the teachers' beliefs are stable and opposed to change and they mirror the instruction the teacher presents to students. Furthermore, these beliefs take the role of a 'filter' through which other teachers' performances are sieved. Academic knowledge and observation of others accordingly lead to screen teacher's own pedagogy. It is of significance to deal with teacher candidate beliefs because this is going to change their stance in the following practices in the classroom. Is it possible to change beliefs or make some amendments to beliefs a teacher possesses? And how to change teachers' beliefs?

Although some research states that it is difficult to change beliefs (Kagan, 1992; Tabachnick & Zeichner, 1984), some ways exist in altering certain beliefs. Developing knowledge of classroom management, pedagogical instruction and subject knowledge can mediate to change preservice teacher beliefs in teacher education programs (Joram & Gabriele, 1998). If the prior beliefs of the teacher aren't addressed, they will cause barriers to instruction, because the new knowledge will be assimilated to existing one (Anderson et al., 1995; Kagan, 1992; Scheurman, 1996; Slotta et al., 1995). Therefore, it is essential to take prior beliefs into consideration when dealing with altering beliefs (Bruner, 1996). Parker (1989) investigated prospective teachers in introductory courses and found out that some conceptions have been changed like beliefs about teaching and teacher knowledge. Nevertheless, not all students changed their way of believing and thinking. Changing beliefs of teachers isn't an effortless work but rather involves longstanding and endurable effort. There are a lot of cases in which student teachers didn't change their beliefs about good teaching in education programs (Olson, 1993). Regardless of difficulty, there are some suggestions to change beliefs in teacher education programs. Richardson (2003) proposed two approaches in education classes (1) to support students to be more tacit and analyse their existing beliefs and understandings of teaching and learning and (2) to support students' practice situation with structured and propositional knowledge they gained during academic classes.

Teachers' beliefs are a valuable and essential part in the research of educational inquiry. These beliefs can affect a teacher's following instruction, assessment and evaluation in the classroom (Pajares, 1992; Munby, 1982). Pintrich (1990) argued that beliefs even can shape the learning of preservice teachers in education programs. Preservice teachers' prior beliefs which were influenced by personal experience, schooling or culture should be investigated by means of quantitative or qualitative assessments to further analyse and if necessary, alter the existing beliefs about teaching and learning. Even though it is difficult to change existing beliefs, it isn't impossible.

Researchers have developed ways of adjusting beliefs and suggested some approaches towards it. Calderhead (1988) suggested teacher educators to promote their student teachers to more metacognitive processes like analysis and evaluation of selves rather than just developing knowledge base to subject matter. Making preservice teachers aware of their own beliefs and conceptions, letting them explore, compare and evaluate with other views are general suggestions to dealing with belief problems (Anderson et al., 1995).

In summary, beliefs of teachers are a crucial part in education and these affect their behaviour in the classroom and implementation of methods. All field teachers are under education responsibility but science teachers, in particular, play a significant role in the education system of one country. Preparing scientific literate pupils for the future is an essential requirement to science teachers. Therefore, science teaching and learning is crucial in teacher education and importance should be focused on science teachers' beliefs and especially to more constructivist beliefs rather than traditional. Reformed beliefs of science is the evolving topic in recent years suggesting a more inquiry-oriented stance towards learning and teaching of science. The following part of this chapter is devoted to detailed investigation of reformed beliefs of science teachers.

2.8 Reformed science beliefs

Science education became the most prominent topic regarding teachers' beliefs due to its complex systems of belief which affects teacher's viewing of students, themselves and science (Bryan, 2012). Henceforth, these beliefs influence the way a teacher adopts practices in his or her class. Beliefs are playing an affecting role in science teachers' practices and further implementation of new practices in the classroom (Pajares, 1992; Richardson & Placier, 2001). Science teachers' belief system and attitude were reviewed in Jones and Carter's (2007) sociocultural model to understand construction and development of science teachers' beliefs. In Figure 4 Sociocultural Model of Embedded Belief Systems, we can observe multiple reciprocal interactions that made up belief systems. This model is circumscribed by the sociocultural context of teachers as peers, pupils or culture. There is no starting point in this cyclical model rather they are all intertwisted. Knowledge, skills and motivation are preconditions for employing a specific instructional practice. As maintained in the model, motivation is affected by attitude towards implementation and instruction. These attitudes embody related belief systems and have either positive or negative direction, which will determine the strength of motivation. As can be seen in the model, science teachers' beliefs are influenced by epistemological beliefs about science, beliefs about teaching science and beliefs about learning science. Thus, epistemological beliefs put up the science teachers' teaching paradigms (van Driel, Verloop & de Vos, 1998). Moreover, self-efficacy, social norms and environmental constraints are also components of belief systems. Self-efficacy is the belief of being able to implement instructional methods (Jones & Carter, 2007), which necessitates teachers to possess this skill. Whereas social norms are the norms a teacher perceives from expectations of others about teaching. Lastly, environmental constraints, which form obstacles in successfully applying instruction as time shortage and resources, corroborate this belief system. In the light of this belief system it can be drawn that a teacher's beliefs about using certain methods in science class cannot be disjoined from teacher's beliefs about science, science teaching and science learning as well as from motivation, self-efficacy about implementing certain practices and specific constraints in application, knowledge about a topic, prior experience and culture one belongs (Jones & Carter, 2007). After all, all these entities make up the belief system of science teachers.

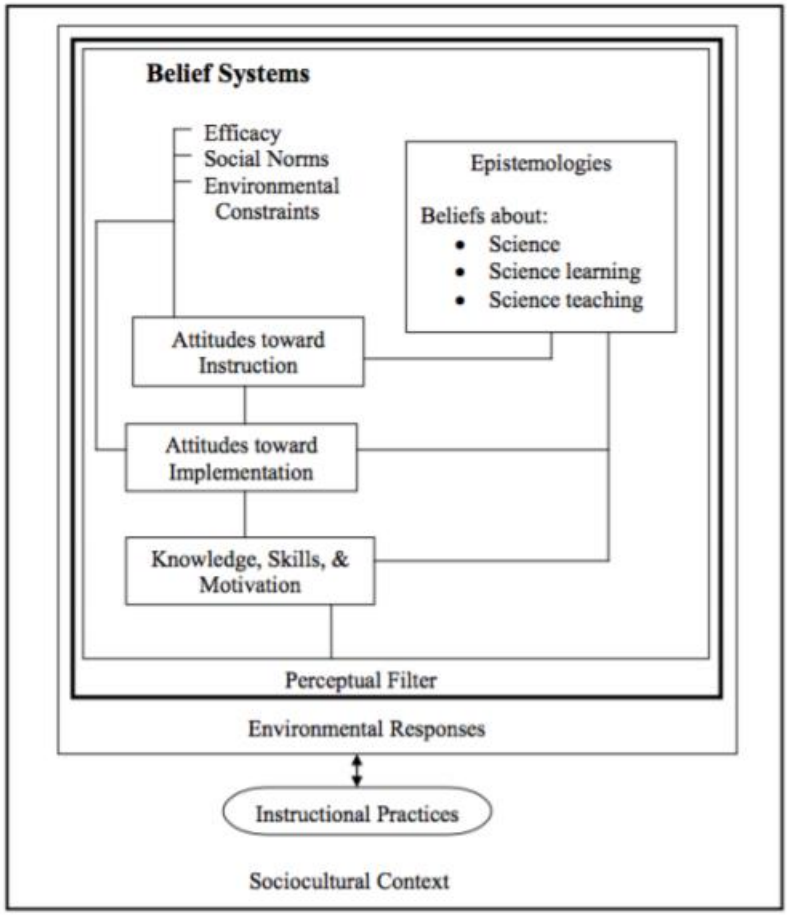

Figure 2.4. Sociocultural Model of Embedded Belief Systems (Jones & Carter, 2007, p.1074).

Teacher belief systems are a key to comprehending and reforming science education (Crawford, 2007; Jones & Carter, 2007). Beliefs of teachers about science, science teaching and learning affect almost all aspects of their practice and guide them to take decisions in instruction (Sampson, Enderle & Grooms, 2013). Therefore, understanding the beliefs of preservice teachers is important in the education of science as it will shed light on the success of reform in the future. A study conducted in University of British Columbia with science student teachers, concluded that 50% of teachers thought themselves as a transmitter of science knowledge to students and another half of them viewed learning of science as uptake of knowledge (Aguirre et al., 1990). Consequently, preservice teachers embraced a more traditional way of teaching, transmissive approach. On the contrary, the study of Larry Bencze et al. (2006) on teachers' beliefs about nature of science found out that Canadian teachers' espoused beliefs, "self-reported claims about the way things are", are consistent with more student-centered and inquiry-oriented methods. Smith (2003) investigated that science teachers' teaching and learning of science were directly related to their prior experiences and beliefs. If student teachers were exposed to more traditional approaches, it would lead their teaching path in more lecture based too.

Educational reform's prior interest is based on the constructivist view of teaching and learning. It emphasizes a movement in teacher's beliefs and practices toward inquiry based views. However teachers' beliefs and related efforts to reform the teaching are not coordinated. Because teachers' beliefs are deep-rooted and insubordinate to changes, which filter the teaching facilities and nature of teaching (Kagan, 1992). The relationship between teachers' beliefs and practices are mutually related. The findings propose that there is a dual connection between teachers' beliefs and practice, "practice can shape their beliefs and beliefs determine their response to science teaching" (Enderle, Grooms & Sampson, 2013, p.5). To be able to ascertain teachers' beliefs about teaching and learning and determining the potential changes can be critical elements in encountering meaningful reform in science education. Because in science education, if the prior beliefs of teachers aren't addressed, this may lead to form some obstacles in instruction, which means that new information will be assimilated to existing ones (Anderson et al., 1995; Kagan, 1992; Scheurman, 1996; Slotta et al., 1995). It is of prior necessity to consider preservice teachers' science beliefs because any new material will be completed, replaced or modified with the existing ones (Bruner, 1996, p.46).

Constructivism movement in science involves philosophical and theoretical rationale for reform in science education. Constructivist approach bases on not only transmitting the knowledge to pupils but encouraging students to build it up actively (Driver et al., 1994). According to the National Research Council (1996) learning science from a constructivist perspective is an active process and "is something students do, not something that is done to them" (p.22). Each of the students do develop their own representation of models and concepts, which they use to make sense of the world and broaden their understanding of the world (Sampson, Enderle & Grooms, 2013). Hence, American Association for the Advancement of Science (1989) emphasized that teaching of science should be compatible with the nature of scientific inquiry. In this case, good science teaching ought to include; starting with questions, participating students actively, focusing on collection and use of evidence and combining knowing and finding out (NRC, 1996). Not only "hands-on" activities but also "minds-on" activities should be employed. This type of practice demands teachers to contribute to students' self-explanations and justification of their work and to other peers. Students must be able to evaluate collected data, make general statements about findings and present findings to class at the same time accepting criticism of others (NRC, 1996).

Contemporary reform efforts in science education were highlighted in the *Project 2061: Science for All Americans* (AAAS, 1989) which set standards to more inquiry-based syllabi. In the USA, a focus on the nature of science knowledge understanding is the main ground on which development and application of scientific concepts occur in education (Ozfidan et al., 2017). Likewise, science education in Turkey also has given importance to the teaching of science like many Western countries (Turkmen & Bonnstetter, 2007). However, comparing Turkey to the USA revealed that science education in the USA is established on teaching science for everyone and creating scientific literate persons (NSES, 1996). Reform-minded teachers in the USA encourage their students to construct their understanding of science through more inquiry-based activities which in turn involve students in a society of thinking and appreciating ideas (Joram & Gabrielle, 1998). Consequently, we can witness that teachers' beliefs about reform in science education will influence their teaching and learning in science. The success of reform struggles are dependent on the support of teachers (Levitt, 2001). Therefore, recognizing and understanding beliefs of preservice science teachers is crucial in the process of educational reform (Bybee, 1993; Haney, Czerniak & Lumpe, 1996).

Educational reform striving in science education favour constructivist views of teaching and learning of science and that being the case of shifting teachers' beliefs toward these approaches (Sampson et al., 2017). Because teachers play the main part in implementing reformed science lessons successfully (AAAS, 1989). A study conducted by Feldman in 2002 with two physics teachers revealed that teacher's beliefs of their role in a student's education were a "*contributing factor in their implementation of the curriculum*" (p. 12). However, a study of Smith and Southerland (2007) examined the nature of relationship between beliefs and practice of teachers which showed "dialectical connection" between them. In other words, one part of teachers' practices were circumscribed to external force in shaping their beliefs and the other half were determined by their enacted classroom beliefs and response to outer force. The fact is that many teachers face difficulties in their practices due to their inadequate knowledge background or lack of thinking differently about science, science teaching and learning. Therefore, it is essential in teacher preparation programs to touch upon the beliefs of science teachers and explore deeply to observe problems before preservice teachers implement practices at schools. Teacher education is the process of constructing on, broadening and reconstructing past experiences (Dewey, 1938). With this in mind, science educators are expected to challenge student teachers' views and enable students to face, change position and improve their beliefs, knowledge and values about teaching and learning (Bryan, Abel & Anderson, 1996). Preservice teachers' engagement on their own reflection of learning and teaching allows insights into experiences on which teacher education programs will be constructed promoting inquiry-based teaching (Simmons et al., 1999). In Figure 5 Experience, memory and the challenge of field experiences, we can see science teachers' shaping their learning and teaching from past experiences. Preservice teachers' past experiences lead them to form episodic memories which influence their beliefs about learning or shaping beliefs about both learning and teaching. Consequently, these beliefs shape their expectation of what and how they learn from science method classes. In the light of this model, science educators should take into consideration helping preservice teachers to "reframe their experience-linked thinking" (Thomas & Pederson, 2003).

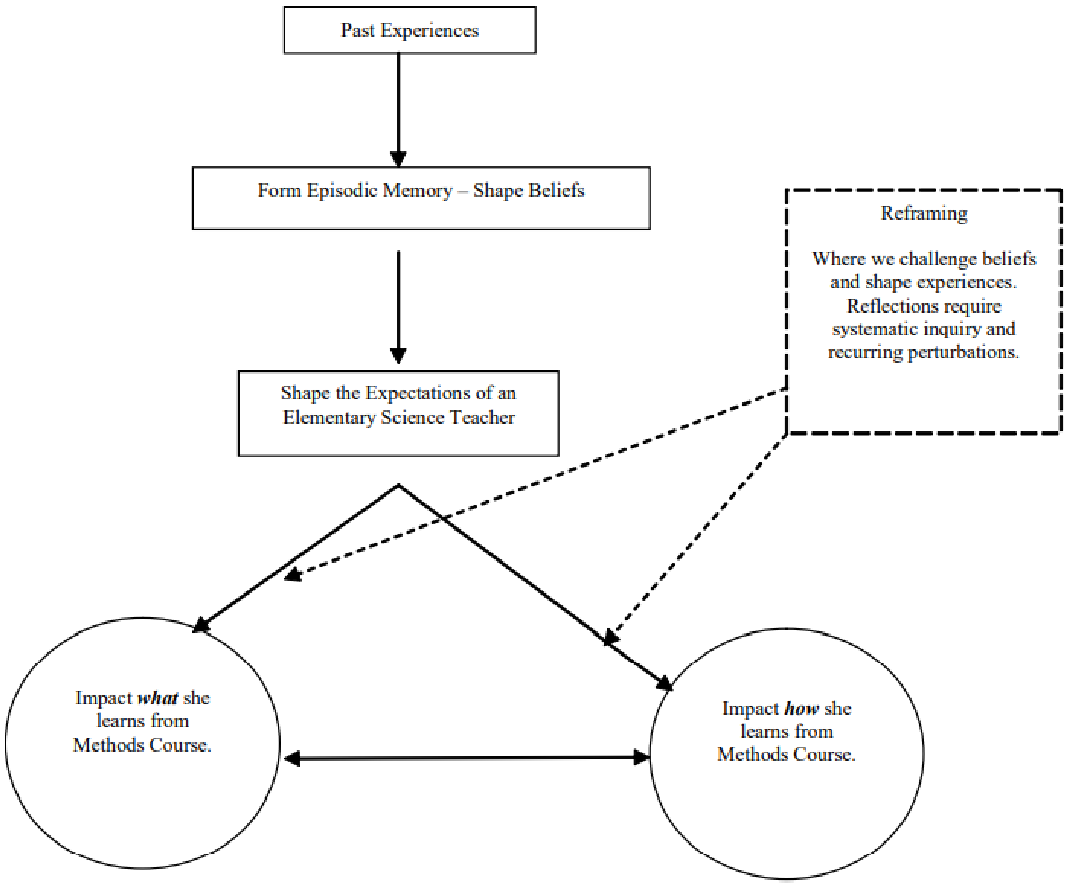

Figure 2.5. Experience, Memory and the challenge of field experience (Thomas & Pederson, 2003).

The reform documents propose philosophical shifting of science teaching and learning (Sampson et al., 2017). This necessitates fundamental changes in teachers' understanding of how people learn and how the lessons ought to be designed. Similarly, these changes are accompanied with defining characteristics of teacher and learning environment. Last but not least, the reform perspective stresses a crucial understanding on the nature of science (Sampson et al., 2017). These scopes, which are objectives for change in the reform efforts, can fulfil as benchmark categories for tools which focus on how science teachers make sense of and accept the notions of reformed science. For this reason, in the following part of the literature review section, four subdimensions of reformed shift in science will be discussed thoroughly.

2.8.1 How people learn about science

One of the characteristics of learning a science is its significance of learning with understanding (Bransford, Brown & Cocking, 2004). But the curriculum puts more emphasis on memory than understanding. An attention to understanding brings to the primary feature of new science learning: its direction to the process of learning (Piaget, 1978; Vygotsky, 1978). Human beings seek to learn more about nature and environment. Their pre-existing knowledge about nature, their beliefs and skills influence the way they organize and interpret (Bransford et al., 2004). Therefore, teachers should pay attention to pre knowledge, naïve conceptions and false beliefs of students as they should be aware of the fact that knowledge construction will be based on them. If students' misconceptions aren't addressed, it will cause a negative effect on learning further. With this in mind, it is essential that teachers elicit pre-existing knowledge of students of subject matter and provide possibility to students to build on their initial knowledge (Bransford et al., 2004).

The core requirement for a constructivist approach is that knowledge isn't transmitted but actively built by learners. One perspective focuses on personal construction of meanings of natural phenomena (Carey, 1985; Carmichael et al., 1990). Another perspective emphasizes on learners' enculturation into scientific discourses (Edwards & Mercer, 1987; Lemke, 1990). Furthermore, knowledge-construction involves student's informal knowledge and its interaction with scientific ways in the classroom (Johnston & Driver, 1990; Scott, 1993; Scott, Asoko, Driver & Emberton, 1994). But not only the large amount of knowledge is adequate to make students expert in inquiry but also their deep understanding of knowledge is important. In acquiring knowledge there is an expert and novice learners, experts use their conceptual understanding to extract information from relevant fields and make relationships or discrepancies which are not apparent to novices (Bransford et al., 2004). Hence, the goal of education is to move novice learners into expert ones by deepening their knowledge and developing conceptual framework. Novices not only outstand with their deep learning but also have metacognitive skills with which they analyse their learning, monitor progress and refer to incomplete areas (Bransford et al., 2004). These metacognitive skills should be incorporated in the context of subject matter teaching which students are learning (White &Frederickson, 1998). These skills aren't generic and if taught them as generic, would lead to failure.

To sum up, learners bring their pre-existing knowledge to classes and they learn new knowledge on building to the previous one. Teachers are responsible for addressing preexisting knowledge and making amendments. The model of the child as an empty vessel is no longer stressed because students construct on the previous knowledge and teachers should create the environment where students can actively think and create (Bransford et al., 2004). Deep learning rather than surface coverage of learning must be enhanced when learning new concepts. Lastly, implementing metacognitive skills into all areas of curriculum, not explicitly, considered to be useful to shift novices to expert learners (Bransford et al., 2004).

2.8.2 Lesson design and implementation

Awareness of students' prior knowledge strengthens teachers' implementation in practice. Teachers make certain amendments and improvements to their instruction and assessment strategies. Paying attention to knowledge, skills and attitudes students bring into class may lead to a broader understanding of pupils for teachers (Bransford et al., 2004). In the light of this understanding, teachers should propose learner-centered classrooms in which they will pay closer attention to each pupil. Duckworth (1987) suggests that in the learner-centered environment, teachers should give activities with "just manageable difficulties" which are challenging enough but don't lead to discouragement. Therefore, it is significant that teachers have adequate knowledge about their students' levels.

In order to provide knowledge-centered environment prominence should be given to what information or subject matter is taught (Bransford et al., 2004). Well-organized and in-depth knowledge is the primary concern in this aspect. There should be connections between concepts to be taught so that pupils can catch up and make relationships of what they were instructed before. Additionally, teachers should be aware of why to teach concepts which in turns lead to deep understanding of students about the topic (Bransford et al., 2004). To put it another way, a knowledge-centered environment encourages doing with understanding than doing hands-on (Greeno,1991). Thereupon, pupils' engagement and interest are primary concerns in the classroom (Prawaf et al., 1992). Moreover, formative assessments or ongoing assessments play an important role in seeing students' thinking and progress during their course of learning and permits teachers to have adequate information about students' preconceptions and where the students are in the "developmental corridor" (Bransford et al., 2004). Assessment-centered classrooms help both teacher and students to monitor their progress and teachers can derive how they should organize the following instructions. But these assessments ought to be learner-friendly rather than scary reminders of lessons. Indeed, they must give students opportunity to ameliorate and revise their thinking (Vye et al., 1998). Finally, designing community-centered classes for students in which development of norms and connection to the outside world are prioritized (Bransford et al., 2004). The norms in the classroom have to stimulate academic risk-taking rather than being shy of not knowing. Teachers are capable of creating an environment in which students can make mistakes and get necessary feedback (Bransford et al., 2004). Students should be encouraged to make links of what they learnt to other fields as well.

To conclude, the lesson design in inquiry-oriented classes must be student-centered and have an attention to what is learnt and why it is learnt. Implementation should be at an in-depth level but at the same time not over confusing. Similarly the assessments ought to be designed in a promoting way of thinking and learning, to the contrary of grades. Community based learning is of necessity in involving students to the outside world as possible. All in all, instructors must participate in designing activities that promote intellectual growth of learners and help learners to organize their work (Bransford et al., 2004).

2.8.3 Characteristics of teachers and the learning environment

Inquiry is considered to be central in science learning and prominent in science teaching (NSES, 1994). This doesn’t mean that all teachers should follow one path, in contrast it requires student experiences as a central strategy in teaching inquiry-oriented lessons. The misconceptions and naïve conceptions brought to class by students are then changed by the resolution disequilibrium assisted by teachers (Driver et al., 1994). Thus, learning is accepted as a process of conceptual change. Teaching approaches adopted by teachers must focus on supplying students with physical experience which cause cognitive conflict and aid learners to bring out new schemes that are adapted to prior beliefs. These approaches or strategies of teachers in class are encouraged through group discussion of students (Nussbaum & Novick 1982; Rowell & Dawson, 1984). In such a group environment, pupils may help each other to solve problems by building upon each other’s knowledge, asking questions to each other and proposing solutions that will aid in moving towards the goal (Brown & Campione, 1994). Correspondingly, enhancing the environment of cooperation in problem solving and argumentation between students boost pupils’ cognitive growth (Evans, 1989; Newstead and Evans, 1995).

The characteristics of teachers in the classroom are based on working to support and reinforce student investigations without directly explaining concepts (Sampson et al., 2013). Individuals are actively engaged in discussions and their meanings are carefully listened to in this reinforcing environment (Driver et al., 1994). Activities are designed so that students can think and reflect with requests for “argument and evidence in support for assertion”. Teachers refer to the development of knowledge and understanding of scientific ideas and how scientists learn the natural world (NSES, 1994). In Figure 2.6 *Traditional-Reform Pedagogy Continuum*, the role of teacher in the classroom is summarised in terms of traditional and reform-oriented, the latter is favoured in constructivism. New orientation suggests that the teacher acts as a coach and facilitator rather than transmitter of knowledge. As stated above, they have a communication with groups and facilitate students’ thinking, not just explaining concepts simply and clearly (Sampson et al., 2013).

Predominance of Old Orientation	Predominance of New Orientation
Teacher Role:	
As dispenser of knowledge	As coach and facilitator
Transmits information	Helps students process info.
Communicates with individuals	Communicates with groups
Directs student actions	Coaches student actions
Explains conceptual relationships	Facilitates student thinking
Teachers knowledge is static	Models the learning process
Directed use of textbook, etc.	Flexible use of materials

Figure 2.6 Traditional- Reform Pedagogy Continuum (Anderson, 2002)

In summary, creating the warm and friendly atmosphere among individuals where they can be actively involved in discussions with other peers trying to understand and comment on phenomena for themselves, where social interaction provides different perspectives to reflect on, is utmost important goal in constructivist learning (Driver et al., 1994). In this way, scientific understanding is constructed by socially talking and sharing the problems with each other. Teacher’s role is to encourage and allow studentsto express their opinions freely. Whereas in traditional classes transmitting and explaining concepts clearly play a role in teaching, coaching and facilitating thinking by helping students to investigate facts is the primary goal of the reform movement in teaching and learning of science.

2.8.4 The nature of science curriculum

Teaching and learning science needs to consider the nature of knowledge to be taught in class. In science education it is important to determine scientific knowledge as symbolic and socially negotiated (Driver et al., 1994). Science objects aren't "phenomena of nature but constructs that are advanced by the scientific community to interpret nature" (Driver et al., 1994, p.5). Consequently in science, the concepts aren't revealed by reading the book of nature, but they are invented and imposed following attempts to interpret and explain phenomena. Scientific entities are unlikely to be discovered by individuals rather they are discovered by a community of scientists (Driver et al., 1994). The studies in the history of science depicts knowledge as an emergence of results from the scientific community as "relativist and result of social processes" (Collins, 1985; Latour & Woolgar, 1979). Nonetheless, Harre (1986) proposes that scientific knowledge is restrained by how the world functions and scientific progress is based on empirical nature. Whether relativist or empiricist approaches are adopted, the main goal of science educators is to aid learners to make sense of ways in which knowledge is generated and validated (Driver et al., 1994).

The science curriculum plays an important role in shaping students' conceptions about science and bringing up scientific literate individuals. Reformed perspective on curriculum of science stresses prominence on focusing conceptual understanding and application of concepts (AAAS, 1993; NRC, 1996). Because students are required to understand present knowledge and improve, make decisions on unfamiliar tasks (Talbert &McLaughlin, 1993). Furthermore, the curriculum should be flexible to change it with students' interests and questions. Last but not least is the focus on the depth of learning a concept rather than just the surface of each topic (AAAS, 1993; NRC, 1996).

As can be seen, the science curriculum should consider the nature of scientific knowledge and draw attention to few concepts but in detail, in depth. Hence, students need to develop their own reasoning abilities and come up with conclusions necessary to do science.

2.9 Importance of examining adaptive expertise skills and reform-oriented beliefs

Examining both adaptive expertise skills and reformed science beliefs of preservice teachers, lead us to see the preparedness of future teachers in the 21st century competitive workplace of schools. Cognitive stance of adaptive expertise and reformed beliefs of science that are open to new changes should move together to achieve desired skills of the new and innovative era. Consequently, adaptive and reform-oriented teachers will have tremendous impact on future science classes facilitating inquiry learning, self-regulation and adaptation to novel and unfamiliar situations. With the reform in the field of science education, teachers should possess adaptive skills and reform-oriented beliefs to apply reformed movement in their practices.

Specifically, the education of pre-service teachers play an important role in preparing the reform-oriented and adaptive teachers. Preservice programs gained prominent significance in preparing prospective teachers in a few decades (Darling-Hammond, 1997). As the 21st century requires reform-minded teachers who "model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and scepticism that characterize science" (NRC, 2000, p.22). In order to prepare teachers for a new and innovative thinking world it is necessary to take into consideration the skills of adaptiveness and reformist movement.

Studies have been conducted to observe the beliefs about the reformed science but studies involving both the adaptive skills and beliefs were not conducted until now. As two variables are both cognitive constructs, they can mostly be related to each other in terms of the epistemological stances (Brown, 1980). Metacognitive skills required for the adaptive skills actually come from the epistemological beliefs of the individuals. If teachers are apt to change or find out some new ways in their practice, first of all teachers should have a positive stance toward teaching and learning, willing to renovate and become lifelong learners.

Transition from less technological society to a more developed world necessitates renewal and update in science education as well (Karaman & Karaman, 2013). Constructivist, inquiry- oriented and adaptive teachers are in need to fulfil the requirements of the new century. It is no doubt that these entities are not fruitful yet because the traditional foundations are at odds with the reform movement in education (AAAS, 1990). Thus, obtaining wider support from teacher educators, on supplying preservice teachers with necessary skills, is of utmost primary goal in the education system. Consequently, this study will explore the level of teachers' adaptive expertise and reformed beliefs. To what extent teachers are adaptive experts and reform-oriented in science education and what kind of assistance should be provided during their preservice years to make them prepare for a tough and changing school environment which demands teachers to adapt and make innovations in their field.

CHAPTER 3

METHODOLOGY

This chapter focuses on providing information about design of the research, sample of the study, instruments used, data collection process, statistical techniques used in data analysis and limitations of the study.

3.1 Research Design

The research design of the study is a quantitative and a survey research method was employed. Survey research relies on asking questions to a sample of a group in order to describe characteristics and some aspects of a sample (Fraenkel & Wallen, 2005). This design purposes to describe adaptive expertise skills and reformed beliefs about science of PT’s chosen from the Faculty of Education. Demographic variables of PT’s on both adaptive expertise and reformed beliefs are explored by this study. The collected data from both questionnaires were used for inferential statistics to see descriptions for academic major, levels of years, gender and work experience of PT’s. The independent variables are grade level, academic major, gender and work experience whereas the dependent variables are adaptive expertise and reformed beliefs.

3.2 Sample

The target population was pre-service science teachers in a research university located in Ankara, Turkey. The accessible population was pre-service science teachers in the department of Education. The university is a public research university located in Ankara, Turkey and the education department ranked in top 100 universities of the World, being 93rd in world universities and first in Turkey (THE, 2021). The faculty of education formed by students from various regions was chosen as the sample of this study. Convenience non-random sampling method was employed as there were already formed intact classes from each major and year PTs present in the groups.

The approximate participants in the study were supposed to be around 400 pre-service teachers. However, the sample of the study reached 272 PTs from the science education departments. The participants were from each major; Elementary Science Education (ESE), Chemistry Education (CHED) and Physics Education (PHED) and pre-service teachers from all levels of years; freshman, sophomore, junior and senior, are involved in the study as participants. From participants 190 subjects were female and 82 were male which constituted 69.9 % and 30.1 % of overall participants, respectively. Additionally, PTs with professional work experience made up 9.6 % of overall participants which meant only 26 PTs out of 272 had work experience in their field.

In Table 3.1 and 3.2 , we can see the distribution of percentage in each major and level of years. As can be seen the majority of participants were from the ESE department; 164 PTs (60.3%) participated in the study. 35 participants from CHED and 73 participants from PHED took part in the survey study. When we observe the level of years, in Bachelor of Science education the year level is 4, but the previous program for CHED and PHED offered a 5 year program with a master program. Thus, we have included two senior groups; senior 4^{th} year and senior 5^{th} year for CHED and PHED. Consequently, study consisted of 65 (23.9%) freshman, 62 (22.8%) sophomore, 68 (25%) junior and 64 (23. 5%) senior 4^{th} grade, 13 (4,8%) senior 5^{th} grade PTs in the science education department of university.

Table 3.1 Descriptive statistics for academic major

Department	N	Percentage
CHED	35	12,9 %
PHED	73	26,8%
ESE	164	60,3%
Total	272	100,0%

Table 3.2 Descriptive statistics for level in college

Level in College	N	Percentage
Freshman	65	23,9%
Sophomore	62	22,8%
Junior	68	25,0%
Senior(4^{th})	64	23,5%
Senior (5^{th})	13	4,8%
Total	272	100,0%

3.3 Instruments

The design of the study is quantitative. The independent variables are academic major, level of years, gender, and professional work experience which are categorical variables and measured on nominal scale. On the other hand, dependent variables are pre-service teachers' reformed beliefs and adaptive expertise skills which are continuous variables and measured on interval level scale.

To see the inferential statistics we have implemented Likert type scale of Adaptive expertise(AE) and BARSTL(Beliefs about Reformed Science Teaching and Learning) questionnaires. In the following sections, two instruments will be discussed in detail.

3.3.1 Beliefs About Reformed Science Teaching and Learning Questionnaire (BARSTL)

The BARSTL questionnaire was designed as an instrument that can be used to address the extent to which science teachers' beliefs about the teaching and learning of science are in the same current with the current reform movements in science education (NRC,1996). The questionnaire was developed by Sampsons, Grooms and Enderle (2013). The BARSTL consists of 32 items which are divided into four subdimensions as how people learn about science (HPL), lesson design and implementation (LDI), characteristics of teachers and the learning environment (CTLE), and nature of science curriculum (NOSC) (Sampson et al.,2013). Each subdimension contains eight questions of which 4 are related to reformed perspectives and 4 are traditional perspectives. The items are scored from 1 to 4 as strongly disagree, disagree, agree and strongly agree (NRC, 1996). In *Figure 3.1*, we can see dimensions of traditional and reformed models.

BARSTL Scales	Traditional Perspective	Reformed Perspective
How people learn about science	Compared with "blank slates" Learning is accumulation of information	What students learn is influenced by their existing ideas. Learning is the modification of existing ideas.
Lesson design and implementation	Teacher-prescribed activities Frontal teaching—telling and showing students Relies heavily on textbooks and workbooks	Student-directed learning. Relies heavily on student-developed investigations, manipulative materials, and primary sources of data.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge Focus on independent work and learning by rote	The teacher acts as facilitator, listener, and coach. Focus on learning together and valuing others ideas and ways of thinking.
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed Focus on breadth over depth	Focus on conceptual understanding and the application of concepts. Curriculum is flexible, changes with student questions and interest. Focus on depth over breadth.

Figure 3.1 Dimensions of Traditional and Reformed minded beliefs (Sampsons et al., 2013)

The content validity of the instrument was checked by a panel of experts who evaluated the scale's items thoroughly and made conclusions that the contents of the instrument were phrased consistently (Enderle, Grooms & Sampson, 2013). The content of BARSTL was based on four main sources (Sampsons et al., 2013): (1) the National Science Education Standards (NRC, 1996), (2) Inquiry and the National Science Education Standards (NRC, 2000), (3) Science for All Americans (AAAS, 1989), and (4) Benchmarks for Scientific Literacy (AAAS, 1993). The construct validity of the instrument was checked by testing each four different constructs as a single construct of the beliefs of reformed movement (Enderle, Grooms & Sampson, 2013). The correlation analyses were performed for each scale to predict the support for each scale. The R^2 values were used to see if they support the hypothesis. From the analyses the high R^2 values were extracted supporting the strong evidence of construct validity of the BARSTL. The reliability of the instrument was checked by Sampson et al (2013) as Spearman- Brown correlation and coefficient alpha, which had values of .80 and .77 respectively indicating satisfactory internal consistency (DeVellis, 2003). The reliability of Cronbach's alpha coefficient in our study was reported for each subdimension separately and as a total. The reliability value for HPL construct was recorded as 0.613, LDI was 0.792, CTLE was 0.646 and NOSC was 0.652. These values indicated the satisfactory internal reliability of subdimensions. Lastly, the total reliability value of instrument BARSTL was found to be 0.692.

To identify the subdimensions of instrument Exploratory Factor Analysis (EFA) of SPSS 26 program was performed as English version of the questionnaire was not employed in Turkey before. EFA is a polychoric correlation to calculate factor structure (Pallant, 2007). Construct validity of the instrument was checked in our study by Principal Component Analysis (Table 3.3). The assumptions for the analysis were checked by the following steps; (1) sample size, (2) factorability of correlational matrix, (3) linearity, (4) outliers among cases. Each assumption will be explained in the following section.

1. Sample size. Pallant (2007) indicated that factor analysis with small sample size is less reliable. It is recommended to have 5 cases for each item (Tabachnick & Fidell, 2007). In our study we have 272 subjects to 32 items, therefore sample size assumption was met with requirements.
2. Factorability of correlational matrix. For a suitable factor analysis there should be correlations of r=0.3 or above (Tabachnick & Fidell, 2007). The correlation matrix in our study revealed to be above 0.3, thus indicating appropriate factorable correlation for factor analysis. Additionally, the Kaiser-Meyer-Olkin (KMO) value was found to be 0.802 and Tabachnick and Fidell (2007) suggested that values 0.6 and above are appropriate for performing Principal Component Analysis. Furthermore, Bartlett's Test of Sphericity ($\chi^2(496)=3398.58$, $p<0.05$) showed the correlations between items were large enough to conduct Principal Component Analysis.
3. Linearity. Factor analysis is based on linear correlations and in our study the correlation between variables was linear.
4. Outliers among cases. Pallant (2007) indicated that factor analysis is sensitive to outliers. In our study, before running any analysis all outliers were checked and removed.

As can be seen above, all assumptions of factor analysis were met and we can run factor analysis to see the construct validity of the BARSTL questionnaire.

The items with loading of 0.33 are considered to have enough relationship with a specific factor and based on Kaiser's criterion of 1 factors whose eigenvalues are over 1 considered to be consistent (Tabachnick & Fidell, 2007).. When we looked at the scree plot (Appendix D), it was seen that four factors show a tendency to be extracted but clear break was shown after factor-2. The four factors explained 45.01% of total variance in the data after rotation. 16.88%, 12.51%, 8.23% and 7.38 % of variances are attributable to factor-1, factor-2, factor-3 and factor-4, respectively (Table3.3).

Table 3.3 Rotated Eigenvalues

Factor	Total eigenvalues	% of variance
1	5.403	16.883
2	4.003	12.509
3	2.634	8.232
4	2.363	7.386

But when we look at the factor loadings of these items, some items don't meet the requirements of being higher than 0.33 (see Appendix D), therefore we need to extract items in our study. The items which didn't predict the subdimension to which they belonged were removed from the data analysis. We can see the items which referred to their subdimension (bolded) and the ones which couldn't define their subsequent subdimensions.

The 32 items of BARSTL were subjected to Principal Component Analysis (PCA) using SPSS version 26. Before performing PCA, the assumptions were checked. Inspection of the correlation matrix revealed the presence of many coefficients higher than .3. The KMO value is .802, higher than recommended value of .6 (Kaiser, 1974) and Bartlett's Test of Sphericity was significant, supporting factorability of the correlation matrix.

Principal component analysis revealed that four factors exceeding eigenvalue of 1 are present in study, but the scree plot shows the clear break after factor-2. Thus, it was decided to retain two factors for further research (Catell, 1966).

The factor analysis of BARSTL identified some items to be measuring the exact construct whereas others didn't measure the subdimension of the questionnaire This finding was supported by the questionnaire authors Sampson et al (2013). Thus, some items are presented according to reform oriented and traditional oriented learning and teaching scales and we need to extract items which don't have higher loading and don't represent the reform-oriented beliefs or traditional beliefs. Consequently, such items as; barstl3, barstl4, barstl6, barstl7, barstl8, barstl10, barstl11, barstl13, barstl14, barstl15, barstl17, barstl18, barstl20, barstl22, barstl24, barstl25, barstl26, barstl27, barstl29 and barstl31 were extracted from the data analysis to achieve the proper results. In conclusion, from a total of 32 items; 20 items were extracted and 12 were retained for further analysis.

3.3.2 Adaptive Expertise Questionnaire (AEQ)

AEQ was initially developed by Fisher and Peterson in 2001 for Engineering students. Adaptive expertise questionnaire consists of 42 items scored from 1 to 6 as strongly disagree, disagree, slightly disagree, slightly agree, agree and strongly agree. The questions are mostly related to application of newly acquired knowledge. The questions in the scale are related to application of the knowledge to new situations and how individuals act to solve the problems; their strategy or techniques used when solving a problem. AEQ has been identified to have four primary constructs such as multiple perspectives, metacognition, goals and beliefs and epistemology. The designed adaptive expertise instrument consists of the epistemological beliefs, metacognition, domain and innovative skills (Fisher & Peterson,2001). These four categories serve as a cognitive approach that help students in applying knowledge and recognizing new situations in which content knowledge can be applied (Fisher & Peterson, 2001). In Figure 3.2, it can be seen that some items refer to multiple perspectives such as "I create several models to see which one I like best" or metacognitive skills like "As I learn, I question my understanding of the new information". Subsequently, this survey has negative worded items as well.

#	Survey Item
	Multiple Perspectives
1	I create several models of an engineering problem to see which one I like best.
2	When I consider a problem, I like to see how many different ways I can look at it.
3 (*)	Usually there is one correct method in which to represent a problem.
4 (*)	I tend to focus on a particular model in which to solve a problem.
5	I am open to changing my mind when confronted with an alternative viewpoint.
6 (*)	I rarely consider other ideas after I have found the best answer.
7 (*)	I find additional ideas burdensome after I have found a way to solve the problem.
8	For a new situation, I consider a variety of approaches until one emerges superior.
9 (*)	I solve all related problems in the same manner.
10 (*)	When I solve a new problem, I always try to use the same approach.
11 (*)	There is one best way to approach a problem.
	Metacognitive Self-Assessment
12	As I learn, I question my understanding of the new information.
13	I often try to monitor my understanding of the problem.
14 (*)	As a student, I cannot evaluate my own understanding of new material.
15 (*)	I rarely monitor my own understanding while learning something new.
16	When I know the material, I can recognize areas where my understanding is incomplete.
17 (*)	I have difficulty in determining how well I understand a topic.
18	I monitor my performance on a task.
19	As I work, I ask myself how I am doing and seek out appropriate feedback.
20 (*)	I seldom evaluate my performance on a task.
	Goals and Beliefs
21	Challenge stimulates me.
22 (*)	I feel uncomfortable when I cannot solve difficult problems.
23 (*)	I am afraid to try tasks that I do not think I will do well.
24 (*)	Although I hate to admit it, I would rather do well in a class than learn a lot.
25	One can increase their level of expertise in any area if they are willing to try.
26	Expertise can be developed through hard work.
27 (*)	To become an expert in engineering, you must have an innate talent for engineering.
28 (*)	Experts in engineering are born with a natural talent for their field.
29 (*)	Experts are born, not made.
30	Even if frustrated when working on a difficult problem, I can push on.
31 (*)	I feel uncomfortable when unsure if I am doing a problem the right way.
32	Poorly completing a project is not a sign of a lack of intelligence.
33 (*)	When I struggle, I wonder if I have the intelligence to succeed in engineering.
	Epistemology
34	Knowledge that exists today may be replaced with a new understanding tomorrow.
35	Scientists are always revising their view of the world around them.
36 (*)	Most knowledge that exists in the world today will not change.
37 (*)	Facts that are taught to me in class must be true.
38 (*)	Existing knowledge in the world seldom changes.
39	Scientific theory slowly develops as ideas are analyzed and debated.
40	Scientific knowledge is developed by a community of researchers.
41 (*)	Scientific knowledge is discovered by individuals.
42 (*)	Progress in science is due mainly to the work of sole individuals.

Figure 3.2 Items for AEQ (Items marked (*) are negative items (Fisher & Peterson, 2001)

The instrument of adaptive expertise was developed by many researchers, too and they have included their views on measuring adaptive skills. For instance, in the development of Carbonell et al`s (2016) instrument consisted of three dimensions such as domain skills, metacognitive skills and innovative skills. The metacognition sub-scale attempts to investigate an individual's self-assessment skills, their performance on overall and evaluation of their work by receiving feedback. The domain skills involve the individual's apprehension of personal growth, capability of engaging adaptivity and amalgamate the new developments to their practice. The last sub-scale is the innovative skills and as the name suggests it concerns the innovation like following new skills, applying the knowledge from one field to another and practicing flexibility. As there is no agreement between researchers on the dimensions of adaptive expertise surveys, it is difficult to see distinct differences between items. Therefore, in our study we have checked the subdimensions of adaptive expertise questionnaire to see if they predict the construct of each subdimension.

The content validity of the scale was checked by the experts in the field of metacognitive and innovative skills. To make the instrument time committing to participants, some items were removed and after the discussion of experts, 11 items which were not consistent adaptive expertise were deleted from the scale (Carbonell et al., 2015). To measure the internal reliability the Cronbach Alpha was stated which concluded the validity of the instrument (Carbonell et al., 2015). The reliability value of Cronbach's alpha of AEQ in our study reported to be .823 which indicates satisfactory reliability of the instrument. Further the reliability values for each subdimension were recorded to see the check the reliability of each construct dimension. The reliability for each subdimensions of AE can be seen in Table 3.6, indicating the satisfactory internal consistency among subdimensions.

Table 3.4 Reliability of subdimensions of AE

Subdimension	N	Cronbach's Alpha
Epistemology	5	0.568
Goals and beliefs	9	0.759
Metacognition	5	0.754
Multiple perspectives	4	0.529

The construct validity was checked by using the exploratory factor analysis to see if the instrument contains two or more dimensions (Pallant, 2007). To see subdimension and item correlation the Factor Analysis was performed using EFA SPSS version 26 program. The assumptions for the analysis were checked before conducting factor analysis by the following steps; (1) sample size, (2) factorability of correlational matrix, (3) linearity, (4) outliers among cases. Each assumption will be explained in the following section.

1. Sample size. Pallant (2007) indicated that factor analysis with less sample size is less reliable. It is recommended to have 5 cases for each item or not less than 150 subjects (Tabachnick & Fidell, 2007). In our study we have 272 subjects to 42 items, therefore sample size assumption was met with requirements.
2. Factorability of correlational matrix. For a suitable factor analysis there should be correlations of r=0.3 or above (Tabachnick & Fidell, 2007). The correlation matrix in our study revealed to be above 0.3, thus indicating appropriate factorable correlation for factor analysis. Additionally, the Kaiser-Meyer-Olkin (KMO) value was found to be 0.833 and Tabachnick and Fidell (2007) suggested that values 0.6 and above are appropriate for performing Principal Component Analysis. Furthermore, Bartlett's Test of Sphericity ($\chi^2(861)=4574.35$, $p<0.05$) showed the correlations between items were large enough to conduct Principal Component Analysis.
3. Linearity. Factor analysis is based on linear correlations and in our study the correlation between variables was linear.
4. Outliers among cases. Pallant (2007) indicated that factor analysis is sensitive to outliers. In our study, before running any analysis all outliers were checked and removed.

As can be seen above, all assumptions of factor analysis were met and we can run factor analysis to see the construct validity of the AE questionnaire.

The items which have eigenvalues greater than 1 are considered to be not suitable for further analysis and therefore should be removed. In the factor analysis of AEQ, it was found that four components have eigenvalues higher than 1 and component 1, component 2, component 3 and component 4 explain 14.43%, 10.41%, 8.5% and 7.22% of total variance, respectively. Consequently, these components make up 40.57 % of total variance in the AEQ (Table 3.7).

Table 3.5 Rotated eigenvalues and percentages of variances

Component	Total eigenvalues	% of variance
Component 1	6.062	14.433%
Component 2	4.374	10.415%
Component 3	3.568	8.5%
Component 4	3.035	7.22%

The scree plot of the components (Appendix D) show the sharp break at component 3, indicating that component 1, 2 and 3 explain most of the variance than the remaining component. From this scree plot, we can decide which components to extract or retain (Catell, 1966).

When we look at the factor loadings of each item on four subdimensions, it is obvious that some items loading for a specific subdimension construct is inconsistent with 0.33 correlation value. Some items don’t meet these requirements showing that these items don’t measure that specific construct. In Appendix D, we can see the loadings for each item in their construct with Principal Component Analysis. The bolded items are retained items referring to their subdimension and other items such as adapt10, adapt12, adapt13, adapt14, adapt15, adapt17, adapt19, adapt21, adapt22, adapt25, adapt28, adapt29, adapt32, adapt33, adapt35, adapt36, adapt39, adapt40, and adapt42 were removed from the further data analysis.

The 42 items of AE were subjected to Principal Component Analysis (PCA) using SPSS version 26. Before performing PCA, the assumptions were checked. Inspection of the correlation matrix revealed the presence of many coefficients higher than .3. The KMO value is .833, higher than recommended value of .6 (Kaiser, 1974) and Bartlett's Test of Sphericity was significant, supporting factorability of the correlation matrix.

Principal component analysis revealed that four factors exceeding eigenvalue of 1 are present in study, but the scree plot shows the clear break after component-3. Thus, it was decided to retain three factors for further research (Catell, 1966).

The factor analysis of AEQ identified some items to be measuring the exact construct whereas others didn't measure the subdimension of the questionnaire. After investigating the Principal Component Rotated analysis, we have decided to remove 19 items and retain 23 items for further research of AE of pre-service teachers.

3.4 Data Collection

Data collection started first by getting Ethical Permission from the Human Subjects Ethics Committee at the university (See Appendix C). After the permission was taken, we requested the course names from the Education department that undergraduate science teachers were taking. After having sorted out the courses which freshman, sophomore, junior and senior were attending, we have asked for permission from instructors to implement questionnaires in their class. At the beginning of the 2019-2020 spring semester, we have arranged schedules with some instructors to apply surveys at their classes and we started applying face-to-face questionnaires. However, with the outbreak of COVID-19 pandemic, we have prepared an online platform for surveys using Google Docs and reached the rest of students by inviting students to take part in the study. Before administration of surveys, the aims of each survey were explained to participants and asked if they were to volunteer to participate in the study. The time taken to complete both questionnaires was about 20 minutes and students were free to withdraw from study if they didn't want to continue.

3.5 Data Analysis

For analysis of the data we have used IBM SPSS (Statistical Package for Social Sciences) Statistics 26 program. After the collection of data, first the examination of missing values was done using the IBM SPSS Statistics 26 program. During the initial stage of data analysis, the percentages of missing values were defined. The percentage of missing values recorded to be 0.4% which is accepted to be low (Pallant, 2007) and the missing values were cleared from the data for further analysis. In the following stage of the analysis MANOVA (Multiple Analysis of Variances) data analysis was employed to see gender differences, grade level and academic major effects on adaptive expertise and reformed beliefs of PTs and get the clear statistical values as means, standard deviation and correlation coefficient. Factor analysis of subdimensions of BARSTL and AE questionnaires were investigated by the SPSS Factor Analysis program to see the internal consistency of subdimension constructs. The detailed results from SPSS will be discussed in the results section and SPSS Factor Analysis programs were discussed in the instrument section.

3.6 Assumptions and Limitations of Research

3.6.1 Assumptions

1. PTs participating in the study answered the items of two surveys honestly and correctly.
2. BARSTL and AEQ were administered under standard conditions.
3. The data were recorded and analyzed accurately.

3.6.2 Limitations

1. The study was limited to only one public university, so the results might not be generalized to the entire country.
2. The study consisted of only 272 PTs.
3. As two instruments' some items were long, it might cause unreliable responses from participants.
4. The study relied on self-reported questionnaires which limits complete objectivity.
5. A further qualitative study should be conducted to infer statements from quantitative data.

3.7 Ethical issues of the Study

When considering the issues of the ethical part of the study it was of prior importance to firstly receive an ethical permission and approval form from the Human Subjects Ethics Committee in Middle East Technical University. Secondly, the participants were asked to answer the questionnaires, if they were not volunteers, they could withdraw from the study. To protect the participants from the physical and psychological harm we ensured safety issues of students. No physical violation or psychological pressure were applied on pre-service teachers. The participants were requested to write their names, university years and majors but if they didn't want to write their names or they didn't want to be known, the confidentiality of participants was protected. Their names were not publicly announced or written in the study report, only their major, gender and college years were of concern. The deception wasn't a case of my study, the participants were informed that the study will be about their beliefs and adaptive skills. They were asked to respond truly.

3.8 Threats to Internal Validity of the Study

Internal validity is defined as the differences on dependent variables coming from independent variables and not due to other unintended variables (Fraenkel & Wallen, 2006). This section is devoted to some threats to internal validity of study. The research study faced some limitations as subjects characteristics, instrumentation, location, loss of subjects or mortality, history and testing. These limitations are discussed in detail in the following sections.

Subject Characteristics

Subject characteristics such as gender, major, age, ethnicity etc. can affect the study (Fraenkel & Wallen, 2006). The study sample comprises pre-service science teachers from all science majors and years. The genders were different and their abilities differed. Thus, it could be a threat to the study when analyzing the data. When the data will be collected, analyzing all at once can lead us to erroneous results because of the characteristics of the subjects. To minimize this limitation, statistical analysis comes to the hand. After entering the data to a statistical program and arranging data obtained from samples according to their year and major, the partial correlation can be done for each year and major to clearly see the differences between each year and major. After this analysis, all data can be analyzed together to see the relationship between adaptive expertise and beliefs about the reformed science movement of all prospective teachers.

Instrumentation

The instrument decay, data collector characteristics and data collector bias are the threats to internal validity. In our study, as instruments didn't change during the data collection instrument decay isn't a threat. Data collector bias can be a threat in our case because when shifting from face-to-face to online administration, we asked instructors of the courses to send emails to their students in order to fill the questionnaires. Thus, maybe students thought they were obliged to fill the forms.

Location

Fraenkel and Wallen(2006) stated that location can affect the results of the study. Taking this in mind, the location of students whom some were in classes and some at home could change their responses and affect the way they participated in study.

Mortality

Mortality or loss of subjects could be a threat to our study. Although the study wasn`t longitudinal, the subjects removed a lot from online administration in the middle of their response. Therefore, it caused a drop of the participants from surveys.

History

The unexpected or unplanned situations which rise up during study can affect consequences of study (Fraenkel & Wallen, 2006). During our study, we faced the most challenging periods of our century; the outbreak of COVID-19 illness. This pandemic situation caused many changes in our life including education. The participants started online education and they were at adaptation periods. This situation may affect their stances and attitudes, affecting their responses correspondingly.

Testing

As the study used two instruments to see the effect of demographics on them, we used the two scales at the same time to accessible participants. So one of the scales can be influencing others. For example, when beliefs scales are used first, students can think that if they have a positive attitude towards science reform means that they will have higher adaptive skills. To prevent the limitation or to minimize the effect, I informed the students about the scales and that they are not affecting each other so that students can act accordingly and their answers will not be collapsing with each other.

CHAPTER 4

RESULTS

This chapter presents the results of the study which were explored in order to provide solutions to research questions. The results are obtained from descriptive and inferential analysis. The descriptive analysis was used to provide information about preservice teachers' adaptive expertise and reformed beliefs about science teaching and learning, while the inferential statistics were used to explore the effects of grade level, academic major, gender and work experience on preservice teachers' adaptive expertise and reformed beliefs about science. The results are presented in the sequence of research questions provided in the introduction chapter.

4.1 Descriptive Analysis

In the descriptive statistics part, the frequency analyses, the mean score, the standard deviation and percentages of respondents on adaptive expertise and reformed beliefs were presented. The first research question about the level of adaptive expertise and reformed beliefs about science of preservice teachers were explored.

Research question 1: What is the level of adaptive expertise and reformed beliefs of science preservice teachers?

The level of preservice teachers' AE and BARSTL was defined by their mean scores and standard deviations. The mean scores were compared to total expected mean scores for adaptive expertise and beliefs about reformed science. The highest total score for AE is 138, whereas for BARSTL is 48. In Table 4.1, it can be seen that total scores obtained from research for each variable are relatively high when referring to the expected total score for each dependent variable. The results indicated that student teachers had significantly high levels of adaptive expertise skills and reformed beliefs about science. Preservice teachers had slightly higher levels of Beliefs about Reformed Science (*M*=37.43, *SD*=5.09) than Adaptive Expertise (*M*=90.00, *SD*=13.46). The prospective teachers had rated 77% on reformed science beliefs and 65% on adaptive expertise. These research results implied that candidate teachers were ready to adopt reformed stances in their lesson implementations and were ready enough to adapt to new or challenging situations.

Table 4.1 Descriptive statistics of AE and BARSTL for science teachers

	Mean	Std. Deviation	N
BARSTLtotal	37.43	5.09	271
ADAPTtotal	90.00	13.46	271

When descriptive statistics were examined on the level of years and major of preservice teachers, in order to see the fluctuations between groups, results didn't reveal the major differences between groups. As it can be seen in Table 4.2, the major of students didn't have an effect on reformed beliefs and adaptive expertise. ESE students (*M*=37.94, *SD*=5.31) had slightly higher levels of reformed beliefs about science teaching and learning than their counterparts CHED (*M*=36.02, *SD*=4.42) and PHED peers (*M*=36.95, *SD*=4.73). Besides, for Adaptive Expertise skills, ESE (*M*=90.92, *SD*=14.10) and CHED (*M*=90.51, *SD*=8.13) preservice teachers proved to be almost similar adaptive experts in their field. However, PHED prospective teachers (*M*=87.71, *SD*=13.92) showed slightly lower levels of adaptive expertise. These results suggest that all major ESE, PHED and CHED have close ranged levels on both adaptive expertise and reformed beliefs about science teaching and learning.

If we analyse the readiness of adaptation to new challenges of teachers according to their level of years, it is seen in Table 4.2 that senior (4^{th} year students) (*M*=98.03, *SD*=16.50) showed the highest point of all other participants. Then it was followed by sophomore students (*M*=93.40, *SD*=8.25), senior (5^{th} year students) (*M*=90.00, *SD*=13.48) and then junior (*M*=86.85, *SD*=9.62). The lowest mean value for adaptive expertise appeared in freshman (*M*=82.12, *SD*=12.38). On the other hand, junior (*M*=39.72, *SD*=4.55) and senior (4^{th} year students) (*M*=39.28, *SD*=5.49) scored nearly equal on reformed beliefs about science. Then, the reformed beliefs of prospective teachers indicated decrease from senior (5^{th} year students) (*M*=37.23, *SD*=4.86) to sophomore (*M*=36.24, *SD*=3.42) and the lowest scores were earned by freshman (*M*=34.40, *SD*=4.77). These results assume that there is no significant change in the level of adaptive expertise and reformed beliefs among levels of years of preservice teachers, but showing slight increase in junior and senior students.

Table 4.2 Descriptive statistics for AE and BARSTL on major and level of years

		Reformed beliefs		Adaptive Expertise	
		M	SD	M	SD
Major	CHED	36.02	4.42	90.51	8.13
	PHED	36.95	4.73	87.71	13.92
	ESE	37.94	5.31	90.92	14.10
Level of years	Freshman	34.40	4.77	82.12	12.38
	Sophomore	36.24	3.42	93.40	8.25
	Junior	39.72	4.55	86.85	9.62
	Senior	39.28	5.49	98.03	16.50
	Senior	37.23	4.86	90.00	13.48

4.2 Inferential Analysis

To investigate the effects of demographic variables such as; level of years, academic major, gender and work experience on AE and BARSTL, MANOVA (Multivariate Analysis of Variances) SPSS analysis was used. MANOVA is employed when there are more than one dependent variable (Pallant, 2007). In this analysis we will explore if there are differences among groups on the dependent variables. Firstly, before the analysis the assumptions were checked for two dependent variables (AE and BARSTL) as follows;

1. **Level of measurement:** Each of the parametric approaches assumes that the dependent variables are continuous so the adaptive expertise and beliefs about reformed science teaching and learning are in continuous scale.
2. **Independence of observation:** The measured adaptive expertise and reformist beliefs are independent of each other and are not influenced by each other.
3. **Random sampling:** The adaptive expertise and reformist beliefs data obtained using a random sample from the population.
4. **Sample size:** The minimum number of cases in each cell is two in our analysis as we have two dependent variables (adaptive expertise and beliefs about reformed science teaching and learning). The total number of cells that we have is sixteen (eight levels of independent variables: freshman, sophomore, junior, senior 4^{th}, senior 5^{th}, ESE, PHED, CHED and two dependent variables for each). In our case we have more than the required number of cases for each cell. In Table 4.3, we can see the number of cases for each independent variable and they are higher than the minimum required case.

Table 4.3 Descriptives

		Value Label	N
Level in College	1	Freshman	26
	2	Sophomore	59
	3	Junior	27
	4	Senior	33
	5	Senior	4
Department	1	CHED	24
	2	PHED	38
	3	ESE	87

5. **Normality and Outliers:**

a. **Univariate normality:** Normality tests for two dependent variables: adaptive expertise and beliefs about reformed science teaching and learning were tested.

For adaptive expertise:

In order to check the normality, the non-significant value should be present in the normality test (Pallant, 2001). As can be seen in Table 4.4, the *Shapiro* –Wilk *p* value is .00 which is less than .05, thus, the distribution is not normal but referring to large sample size (Pallant, 2001) we assume that the distribution is normal. Furthermore, in order to check normality we can check skewness and kurtosis values, which are .33 and 1.25 respectively (Table 4.5), showing the normality of the distribution in range between +2 and -2 (Pallant, 2001).

Table 4.4 Test of Normality

	Statistics	Df	*p*
Barstltot	0.98	272	0.1
Adaptot	0.98	271	0.0

For beliefs about reformed science:

In order to check the normality, the non-significant value should be present in the normality test (Pallant, 2001). As can be seen from Table 4.4, Shapiro –Wilk *p* value is .01 which is less than .05, thus, the distribution is not normal but referring to large sample size (Pallant, 2001) we assume that the distribution is normal. Moreover, we can also check skewness and kurtosis values, which are .33 and -.06 respectively showing the normality of the distribution in range between +2 and -2 (Pallant, 2001). Skewness and Kurtosis values for each independent value are also shown in Table 4.5. It can be seen that all skewness and kurtosis values are between the range of +2 and -2, showing the normality distribution of the distribution.

Table 4.5 Skewness and Kurtosis values for dependent variables

	AE		BARSTL	
	Skewness	Kurtosis	Skewness	Kurtosis
Major				
ESE	.79	.92	.45	-.38
CHED	.57	-.46	.81	1.89
PHED	-.78	.47	-.44	.28
Level of years				
Freshman	-.95	1.34	.71	1.08
Sophomore	.17	.07	-.01	-.52
Junior	.42	-.49	.35	-.16
Senior	.51	.29	.09	.29
Senior	-.34	-.34	.46	.95
Gender				
Female	.37	1.15	.19	-.16
Male	.25	1.79	.62	.22

b. **Univariate outliers**

For univariate outliers the extreme values have been explored separately for BARSTL total and Adaptive expertise total. Firstly, the assumed total high values for BARSTL and Adaptive expertise are 48 and 138, respectively. From Table 4.6, we can see that there is one extreme outlier for case number 168, so the case was cleared from data to continue the analysis.

Table 4.6 Extreme Values

			Case Number	Value
BARSTLtot	Highest	1	168	52
	Lowest	1	79	25
ADPtot	Highest	1	141	131
	Lowest	1	111	46

c. **Multivariate normality and multivariate outliers**

To check multivariate normality, the maximum value from Table 4.7 Mahalanobis distance was checked, which is 14.724. Then, the comparison of this value with the critical values table adapted from Tabachnik and Fidel (1996) should be investigated. As we have two dependent variables, the critical values table`s value is 13.82 but the analysis value is 14.724 telling us that there is at least one outlier in the dataset. From sorting the data we have found that person of ID=71 has a score of 14.724. Because there is only one case regarding the outlier and it doesn't interfere with the data, as it is not too high we are going to leave this person (Tabachnick & Fidell, 2007, p.72).

Table 4.7 Residuals statistics

	Minimum	Maximum	SD	N
Mahal. Distance	.005	14.724	2.090	270
Cook's Distance	.000	.026	.004	270

6. Linearity

To check the linearity assumption some plots were drawn to see the straight-line relationship between dependent and independent variables. Figure 4.1 shows the relationship between adaptive expertise and beliefs about reformed science with students` department and from the plot it is seen that there is no evidence of non-linearity and consequently we can state that linearity assumption is satisfied.

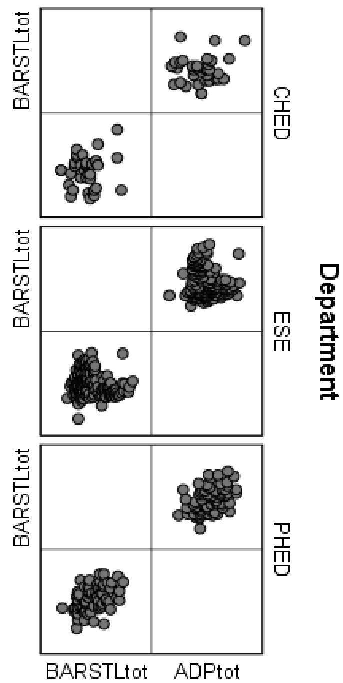

Figure 4.1 Relationship between AE and BARSTL with departments

Figure 4.2 shows the relationship between adaptive expertise and beliefs about reformed science with students` level in college and from the plot it is seen that there is no evidence of non-linearity and consequently we can state that linearity assumption is satisfied.

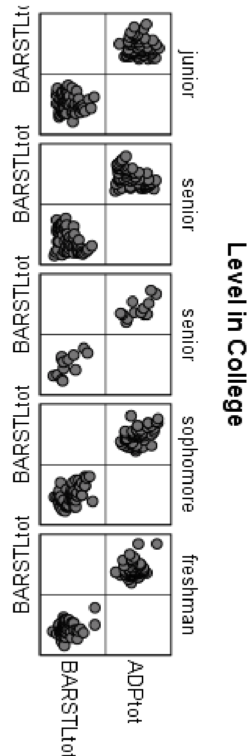

Figure 4.2 Relationship between AE and BARSTL with level of years

7. Multicollinearity and Singularity

From Table 4.8, it is seen that Pearson Correlation value for two dependent values (Adaptive Expertise and BARSTL) is .06 which means there is a moderate correlation between two variables. According to Pallant (2001), slight correlations between variables are best for MANOVA and correlations up to 0.8 or 0.9 are of concern. Therefore, multicollinearity and singularity assumptions are satisfied in our case.

Table 4.8 Correlations

		BARSTLtot	ADPtot
BARSTLtot	Pearson Correlation	1	.06
	N	272	271
ADPtot	Pearson Correlation	.06	1
	N	271	272

8. Homogeneity of variances

For adaptive expertise:

When we look at Table 4.9, we see that the *p* value is 0.00 and $p<0.05$ and we conclude that there is a violation of homogeneity of variances (Pallant, 2001). However, according to Stevens (2002) if the group sizes are equal (largest/smallest<1.5), the violation of assumption has the minimal effect on analysis. In our study, the group sizes were equal, showing a small ratio when large groups divided to smaller ones, hence we can assume that variances are equal.

For beliefs about reformed science:

When we look at Table 4.9, we see that the p value is 0.00 and $p<0.05$ and we conclude that there is a violation of homogeneity of variances (Pallant, 2001). Nonetheless, according to Stevens (2002) if the group sizes are equal (largest/smallest<1.5), the violation of assumption has a small effect on further analysis. In our study, the group sizes were equal; showing a small ratio when large groups divided to smaller ones, hence we can assume that variances are equal.

Table 4.9 Levene's Test of Equality of Error Variances

	Levene Statistic	df1	df2	Sig.
BARSTLtot	4.37	30	78	.00
ADPtot	3.01	30	78	.00

9. Homogeneity of variances -covariance matrices

When we look at Table 4.10, we see that the significance value is 0.095 which is $p > 0.001$ (Pallant, 2001). Henceforth, this shows no violation of assumption.

Table 4.10 Box's Test of Equality of Covariance Matrices

Box's M	89.009
F	1.281
df1	48
df2	1771.194
Sig.	.095

To sum up, all the assumptions of MANOVA for two dependent variables of AE and BARSTL were met and we can further run the SPSS Analysis program to see the differences between demographic effects of independent variables; grade level, academic major, gender and professional work.

4.3 Effects of Demographic Variables on AE and BARSTL

The demographic variables were of concern to measure in our study. Four independent variables will be analysed in the following sections for both AE and BARSTL. Preservice teachers' grade level, academic major, gender and professional work experience effects on adaptive expertise and reformed science teaching and learning beliefs will be discussed in detail.

4.3.1 Grade level and Academic major

Research question 2: Is there a difference between preservice teachers' level of years regarding their adaptive expertise skills and reformist beliefs? Are senior level students more adaptive and reform-oriented in their teaching?

Research question 3: Do preservice elementary science teachers, chemistry teachers and physics teachers differ in terms of adaptive expertise and reformist beliefs?

A two-way between groups multivariate analysis of variance was performed to investigate grade level and academic major differences of pre-service teachers in adaptive expertise and reformist beliefs. Two dependent variables were used: adaptive expertise skills and beliefs about reformed science teaching and learning. Two independent variables were used: level in college and academic major. Preliminary assumptions were tested to check for normality, linearity, univariate and multivariate outliers, homogeneity of variances-covariances matrices and multicollinearity with no serious violations observed. The results of MANOVA are shown in Table 4.11. There was no significantly statistical difference between academic major of pre-service teachers ($F(4,152)=1.587$, $p=0.181$; Wilks` Lambda= 0.922; $\eta^2=0.039$) suggesting that elementary science education, chemistry education and physics education students didn't differ in their adaptive expertise skills and beliefs toward reformed science. The partial eta squared of 0.039 indicated that 3.9% of the variance in dependent variables can be explained by academic major. However, there was a statistically significant difference between pre-service teachers grade levels on dependent variables, ($F(8,154)=5.108$, $p=0,000$; Wilks` Lambda=0.625; $\eta^2=0.210$). Thus, the partial eta squared of 0.210 showed that the 21% of the variance in dependent variables can be explained by level of years. To measure effect size in grade level and major, the partial eta squared results were used. The values were 0.039 and 0.210 for major and grade level, respectively. According to Cohen(1988), it is suggested that there is a medium effect for major and large effect for grade level.

In the results of grade level and academic major, it was revealed that there is a statistically significant interaction between grade level and major ($F(10,154)=1.948$,

p=0,043; Wilks` Lambda=0.788; η^2=0.112). To clarify, when grade level increases, the ESE, CHED and PHED students mean scores increase. In other words, the influence of grade level and academic major on AE and BARSTL depended on each other. The partial eta squared value of 0.112 showed that the 11.2% of the variance in dependent variables was explained by academic major and level of years altogether and it was regarded as a small effect.

Table 4.11 MANOVA results for grade level and academic major

Independent variables	Wilk's lambda	F	Df	Significance p	Eta squared η^2
Grade level	.625	5.108	8.000	.000	.210
Academic major	.922	1.587	4.000	.181	.039
Grade level*Academic major	.788	1.948	10.000	.043	.112

For the purpose of investigating which dependent variable showed differences on grade level and academic major, the follow-up univariate analyses of variance were conducted and the significance was tested by using the Bonferroni adjustment method that reduces Type 1 error. The alpha level is identified by dividing original alpha level (0.05) to the number of dependent variables (2) (Pallant, 2001). In our study, the alpha level was found to be 0.025 by dividing 0.05 to 2. In this case, the effects on the dependent variables were interpreted by referring to Bonferroni adjusted alpha level of 0.025. In Table 4.12, the follow-up analyses for pairwise comparisons are displayed. According to the table, AE (F(4,149)=10.256, p=0.000, η^2=0.345) reached a statistically significant difference in mean scores on level of years of participants. Consequently, freshman, sophomore, junior and senior students mean differences on AE were significantly high. Nevertheless, BARSTL (F(4,149)=1.791, p=0.139, η^2=0.084) didn't show a statistically significant difference of mean scores. Likewise, no statistically significant interaction was found for both AE (F(5,149)=1.328, p=0.261, η^2=0.078) and BARSTL (F(5,149)=2.541, p=0.035, η^2=0.140).

Table 4.12 Follow-Up Pairwise Comparisons

IV	DV	Df	F	*p*	Partial η^2
Grade level	BARSTL	4	1.791	.139	.084
	AE	4	10.256	.000	.345
Academic major	BARSTL	2	.615	.543	.016
	AE	2	2.539	.085	.061
Grade level*Academic major	BARSTL	5	2.541	.035	.140
	AE	5	1.328	.261	.078

The Scheffe test was implemented to determine which pairs cause significant grade level differences with respect to AE. This test is the most cautious method to reduce risk of Type 1 (Pallant, 2001). In Table 4.13, a statistically significant mean difference of AE in terms of grade level can be seen. An inspection of the mean scores of adaptive expertise indicated that senior 4th level students showed significantly higher expertise skills (*M*=108.06, *SD*=3.029) than freshman (*M*=89.15, *SD*=3.392) and senior 5th (*M*=83.5, *SD*=7.403). Furthermore, senior 4th level participants had moderately higher AE skills than sophomore (*M*=93.16, *SD*=2.607) and junior (*M*=90.62, *SD*=3.250). Eventually, senior 4th level participants had high AE skills and were more adaptable to new changes and open to innovative steps in the teacher career.

Table 4.13 Multiple Comparisons of mean differences for AE

DV	Grade level	Grade level	Mean differences	Significance
Adaptive Expertise	Freshman	Sophomore	4.0156	.346
		Junior	1.4758	.977
		Senior (4th)	18.9068*	.000*
		Senior (5th)	5.6538	.779
	Sophomore	Freshman	4.0156	.346
		Junior	2.5399	.755
		Senior (4th)	14.8911*	.000*
		Senior (5th)	9.6695	.255
	Junior	Freshman	1.4758	.977
		Sophomore	2.5399	.755
		Senior (4th)	17.4310*	.000*
		Senior (5th)	7.1296	.595
	Senior (4th)	Freshman	18.9068*	.000*
		Sophomore	14.8911*	.000*
		Junior	17.4310*	.000*
		Senior (5th)	24.5606*	.000*
	Senior (5th)	Freshman	-5.6538	.779
		Sophomore	-9.6695	.255
		Junior	-7.1296	.595
		Senior (4th)	-24.5606*	.000*

*The mean difference is significant at the .025 level

4.3.2 Gender and Professional work experience

Research question 4 : Do males and females differ in terms of overall adaptive expertise and reformed beliefs in science education?

Research question 5 : What is the impact of preservice teachers` professional work experience on adaptive expertise and reformist beliefs?

After finding the answers to previous research questions about whether grade level and major affect AE and BARSTL variables, we were also interested if gender and work experience of teacher candidates influenced their AE and BARSTL skills. A two-way between groups multivariate analysis of variance was performed to investigate gender and professional work experience of pre-service teachers in adaptive expertise and reformist beliefs. Two dependent variables were used: adaptive expertise skills and beliefs about reformed science teaching and learning. Two independent variables were used: gender and work experience. Preliminary assumptions were tested to check for normality, linearity, univariate and multivariate outliers, homogeneity of variances-covariances matrices and multicollinearity with no serious violations observed. In Table 4.14, the results for each independent variable are displayed. There was no statistically significant difference between gender of pre-service teachers ($F(2,77)=0.983$, $p=0.379$; Wilks` Lambda= 0.975; $\eta^2= 0.025$) suggesting that males and females didn't differ in their adaptive expertise skills and beliefs toward reformed science. The partial eta squared of 0.025 indicated that 2.5 % of the variance in dependent variables can be explained by gender. Similarly, the professional work experience ($F(2,77)=2.240$, $p=0.113$; Wilks` Lambda= 0.945; $\eta^2= 0.055$) of participants hadn't affect PTs' adaptive expertise and reformed beliefs about science. The 5.5% of the variance in dependent variables can be explained by work experience. Thus, we can conclude that neither gender nor professional work experience had any effect on AE and BARTSL skills of PTs.

Table 4.14 MANOVA results for gender and work experience

Independent variables	Wilk's lambda	F	df	*p*	Eta squared η^2
Gender	.975	.983	2.000	.379	.025
Work experience	.945	2.240	2.000	.113	.055

4.4 Summary of results

- The descriptive analysis showed that PTs possess a significantly high level of AE and BARSTL. PTs are adaptive experts enough to meet new changes and innovate in their future workplace and in addition PTs are aligned in the reform movement of science education.

- The results of inferential statistics, conducted by MANOVA, revealed that the level of years of prospective teachers affects the AE and BARSTL views of teachers.
- The senior participants showed a higher level of adaptive expertise skills than freshman, sophomore and junior students.
- However, the results of the study didn't show a significant difference between the academic major of PTs on AE and BARSTL.
- Thus, ESE, CHED and PHED prospective teachers didn't differ statistically significantly on their adaptive skills and beliefs about reform movement in science.
- Furthermore, there was an interaction between academic major and level of years of PTs. That is to say that the effect of academic major on AE and BARSTL depended on whether PTs are freshman, sophomore, junior and senior levels at university.
- In addition, the analysis of MANOVA was conducted to see gender and work experience influence on AE and BARSTL of PTs. Gender of PTs, whether they are female or male, didn't affect their adaptive expertise skills and beliefs of reformed science. Moreover, there were no statistically significant mean differences of PTs who had work experience and the ones who didn't have any work experience as a teacher.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

This chapter represents discussions of the results, conclusions and implications of the study and presents some recommendations for further studies.

5.1 Discussions of the results

The discussion of the results part will be examined in two sections; first section will cover the results of demographic variables on adaptive expertise and second part will cover the results of demographic variables on reformed beliefs of preservice science teachers.

Firstly, AE level of PTs showed that teachers possessed a considerably high level of adaptive skills and were ready enough to adapt to upcoming conditions. PTs' cognitive ability to innovate and become a lifelong learner by using their motivational and self-efficacy beliefs proved to be high in their practice. Self-efficacy which refers to the capability to perform actions at a determined level (Bandura, 1997) linked with motivational efforts to overcome challenging conditions (Newton, 1993). Thus, teacher expertise of PTs emerged from the related self-efficacy beliefs in science teaching and motivational endurance in science teaching and learning. Indeed, not only self-efficacy beliefs but also self-regulatory assessments that involve PTs in their learning process actively by using strategies to achieve goals (Zimmerman, 1989) appeared to be high in PTs metacognitive abilities. By the same token, science PTs showed sophisticated levels of multiple perspective stances emphasizing the ability of approaching the problem with various strategies including both innovative and efficient ways. Epistemological views as well as the goals and beliefs about the nature of science and learning proved to exist of higher levels in PTs practices.

The qualitative studies of AE in the field of education (Crawford et al., 2005; Anthony, Hunter & Hunter, 2015) support the need for adaptive skills development of PTs emphasizing that PTs education is the base ground for assuring lifelong learning (Bransford et al., 2004). Therefore, it can be concluded that the quality of materials covered, the appropriate courses and experiment lessons taken during preservice education encourages students to become more adaptive experts than the other counterparts. The public university, in which study took place, has the education department ranked in top 100 universities of the World, being 93rd among world universities and first in Turkey (THE, 2021). Consequently, the education of preservice programs affect PTs lifelong learning and professional development significantly (Bransford et al., 2004). It can be predicted that by applying the adaptiveness in the practices, teachers' cognitive capacity of comprehending and advancing in a complex, changeable and knowledge-concentrated world will be higher (Bransford et al., 2000).

In the following step, the academic majors of PTs according to AE were indicated. The two-way multivariate analysis of variance (MANOVA) had been conducted. The participants of the study were ESE, CHED and PHED science teachers. As it concluded, there was no significant difference between each academic major. The importance of studying AE in the field of education emerges from the need of science teachers adapting to rapid advances in the field of science (Crawford et al., 2005). In the light of these advances, science teachers should learn continuously and embody new knowledge into their instruction. The lack of study between majors of science teachers in terms of AE, made this study progress in order to see if the differences occur between science teachers. However, in other fields such as engineering, medicine and business nearly the same results were encountered. In engineering fields, the differences between different disciplines from engineering faculties haven't been identified (Fisher & Peterson, 2001). Similarly, the participants of medicine disciplines who have completed the innovative dimension of practices of AE didn't demonstrate presence of discrepancy among majors

(Mylopoulos & Regehr, 2009). Thus, these results are consistent with the study of science teachers either, showing no distinction between academic majors of teachers. It is important to note that education faculty offers the same opportunities for all PT science teachers during their courses. Moreover, the higher education curriculum for science teachers provides equal enrolment for the courses which may assist the development of AE skills.

Furthermore, the grade level of PTs differing on AE was explored. This study revealed a statistically significant effect of years of study on PT's AE skills, explaining 21% of variance. In other words, the effect size of the grade level of PT's on AE was high (Pallant, 2001). When the mean scores of PTs from each level of years were compared, the senior 4th grade students showed a high level of AE skills. Similarly, in the research of Fisher and Peterson (2001) with biomedical engineering students indicated that the average score of AE differed across levels of years showing increase from freshmen to seniors. Ozturk and Yalvac (2015) also reported that as the year progresses and as more experience gained, individuals have higher AE mean scores. Likewise, the study of Walker et al (2006) with biomedical engineering students suggested that fourth-year students came up with more innovative solutions than the first-year students. In this study the results of seniors (4th graders) with other counterparts showed significant differences, too. The undergraduate level of science teachers is normally four years but for some major such as Chemistry and Physics education a 5-year education was compulsory according to previous education program in this public university, consequently the new program and the old program PTs participated in this study and they were also labelled as seniors (5th graders). But when comparing senior 5th graders to other levels, the results indicate no possession of high AE mean scores. This may be due to the number of participants because the old program comprised 4.8% of participants in total. Next, considering senior 4th level and juniors mean scores of AE, the high difference between two groups exists. On the contrary, the study of Mylopoulos and Regehr (2009) revealed that there was no difference across years of study in medical students' AE, who were third- and fourth-year students. But in the science education field the year between third and fourth grades is an important factor for developing more professional views. At the senior level, PTs practice their instruction in method classes and apply them in real classes which gives them the opportunity to develop AE in real-life experience. While all grade levels' AE differed according to senior (4^{th} year) students, there were no statistically significant differences between freshman, sophomore and junior levels. These results can be explained by the time which development of AE takes and students can gain more AE characteristics over time. Thus, the teacher's expertise which is recognized as one's orientations, goals and inventiveness brings forth over time (Schoenfeld, 2011).

Moreover, in the study the interaction effect between grade level and academic major was reported. When the grade level of students increases, ESE, CHED and PHED students mean scores increases respectively. The ESE preservice teachers who were in their senior year hold more sophisticated AE skills than freshman, sophomore and junior year PTs. Correspondingly, the CHED and PHED senior prospective teachers possessed higher levels of AE when compared to other ranks.

Additionally, the gender effect of PTs on AE was investigated. Surprisingly, the results bring to light no significant differences between male and female participants and indicate that only 2.5% of variance can be explained by gender. Considering these results, it encourages the fact of reducing the gender gap in the education field. But the point about enrolment of male students to education departments cannot be overlooked here. Even in this study male participants consisted of 82 individuals whereas female participants were of 190 subjects. Thus, the number of female participants was approximately twice of males.

The current study also examined if PTs who have the work experience differed from the ones who didn't have experience on AE skills. Earlier studies in the field of AE suggested that AE was affected by the work experience of individuals (Martin et al., 2006; Fazey et al., 2005; Kalyuga, 2009; Ozturk & Yalvac, 2015; Anthony et al., 2015). However, this study hadn't concluded a statistical difference between experienced and inexperienced teachers on AE. The conclusion can be explained by the fact that PTs who had professional work experience in their fields constituted only 9.6% from overall participants. Thus, only 26 PTs had professional work experience during their education periods as full-time, part-time or private tutors. In Turkey, according to workforce statistics the unemployment rate is 10.4% and particularly, educational organizations comprise the highest rate in these statistics (TSI (TUIK), 2017). According to Higher Education Institute (YOK) (2016) there are 92 education faculties in Turkey and each year 228 thousand teachers graduate from education major. However, along with quantitative increase, the teacher employment problems arise. Therefore, the employment difficulties even after graduation leaves no grounds to PTs during their education periods. On the contrary to findings of this study, Ozturk (2015) in her study with experienced and inexperienced engineers found out that professional work experience was an affecting factor in AE and concluded that engineers with experience possessed more overall dimension scores than the ones with no experience. Similarly, in their qualitative research of AE in mathematics education, Anthony et al (2015) stated that teachers' AE develop throughout their teaching experience. However, Mannikko and Husu (2019) proposed that AE development doesn't occur automatically with years of experience but the changing and challenging environment with self-guided and peer-guided support can enhance improvement of AE.

In the second section of the discussion part, the reformed beliefs PTs possessed are going to be investigated according to PTs demographic variables. Before the exploration of the PTs' demographic effects, the overall level of PTs was explored to see if they are aligned to reform movement in science. The descriptive analysis revealed that science teacher candidates scored 78% on the reformed beliefs indicating a considerably high level of coordinating reformed movement in science teaching and learning. Thus, the findings suggest that PTs hold more reformist aspects of teaching and learning science than traditional teacher-centered views. The obtained mean scores of PTs imply that future candidates believe that (a) students learn by modifying their existing ideas, (b) instruction should be student-directed relying on student-developed exploration, (c) teacher should act as facilitator focusing on learning together and valuing other ideas and

(d) the importance should be placed on conceptual understanding and depth learning. The results of this study were consistent with the results of the study of Levitt (2001) with elementary science teachers, which revealed that the beliefs of teachers were non-traditional about teaching and learning science emphasizing principles of reform. To put it another way, teachers' beliefs about teaching science were aligned with the elements of philosophy underlying the reform movement of science education. On the contrary, Karaman and Karaman (2013), who conducted research in a public university of Turkey, found out that Turkish PTs scored moderately on reform ideas about student learning and nature of science curriculum by dominating with their more traditional views. Another research which compared American and Turkish teachers' reformed beliefs unveiled the fact of United States' teachers (M= 95.50) holding more reformed beliefs about science teaching and learning than teachers who are from Turkey (M=87.00) (Ozfidan et al., 2017). Although the science education programs in Turkey are considered to be problematic with low achievements (Ozden, 2007), the redesigned curriculum in science education (MoNe, 2013) strives to follow the constructivist approach in science. The contribution of this study to PTs preparation programs is essential, after all, the beliefs of preservice teachers about reformist perspectives in science will affect their following practice in teaching careers.

In the light of investigating the level of reformed beliefs in PTs, the academic major differences of participants were explored in the same manner. This study revealed that there was no statistically significant difference between ESE, PHED and CHED PTs holding the reformed views about science. This may have been due to the similar courses they take in the Faculty of Education which encourages their view on the constructivist approach of instruction. Correspondingly, the study of Karaman and Karaman (2013) with elementary and science teachers reported that there was no significant difference between mean scores of elementary (M=2.65) and science teachers (M=2.62) indicating the absence of a gap between majors in science education faculties. However, in their study the researchers found out that teacher candidates viewed more traditional perspectives in their practice rather than a reformed approach in science teaching

(Karaman & Karaman, 2013). Moreover, Uzuntiryaki and Boz (2006), who studied CHED prospective teachers' beliefs regarding the teaching of chemistry, stated that CHED teachers had intermediate constructivist beliefs about teaching chemistry. Likewise, Thomas and Pederson (2003) identified that ESE teachers weren't reformed yet in viewing themselves as student-centered instructors. Despite the variety of findings in the field of majors, the current study indicated that there was no outstanding difference between academic fields of participants and at the same time PTs hold more reformed views than traditional in their implementations.

Another demographic variable which was supposed to have an effect on teachers' development of reformed beliefs is the level of years of participants. Interestingly, it was exposed that there was no difference between freshman, sophomore, junior and senior level of students' possessing reformed beliefs. The current study expected that senior level participants would pose more reformed views than other grade levels. However, all levels have almost similar levels of BARSTL showing that beliefs toward the reformist perspective of teaching and learning science didn't change over the time. Even though the professional development opportunities encourage teachers to improve their reform-based pedagogy, teachers retain their view of more traditional approaches in classes (Lotter, Harwood & Bonner, 2007; Luft, 2007; Luft, Roehrig & Patterson, 2003). Teachers' beliefs about their role in the class, teaching the science and the mandated curriculum can be obstacles for implementing reform and innovative practices (Olson, 1981; Yerrick, Parke & Nugent, 1997). Thus, it is important to emphasize that teachers' beliefs about reform cannot be expected to be changed in a certain amount of time but with the proper development strategies the beliefs can be modified to employ innovative practices than traditional. Teachers have their own pace to change their implementation of reform (Levitt, 2001). Similarly, the professional work experience of participants in this study revealed that there was a lack of gap between the experienced teacher and inexperienced teacher implementing reform. The findings are quite unexpected due to the behaviour and belief interaction. Evidence suggests that beliefs and behaviours interact in a way that one can bring changes in another (Guskey, 1986). With the practice in classrooms, the change in beliefs of teachers is assumed. Because teachers learn from their practice and experience and need time to reflect on (Levitt, 2001). When referring to the importance of teaching practice in the classrooms, the fact of unemployment rate of teachers shouldn't be overseen. The most participants of the study weren't engaged in professional work experience while only a small percentage could have worked in the education institutions.

Finally, the gender effect on PTs view of reform-oriented teaching was investigated. The study found out that neither female nor male participants had significant differences with respect to reformed beliefs. Even though there has been progress in the gap of gender in teacher education, sexism is still a concern for some institutions (Zittleman & Sadker, 2002). By showing no difference between genders, the current study indicated that at least in this university no gap of sexism in the teacher education process exists. On the contrary, the examination of Karaman and Karaman (2013) of reformed beliefs of PTs regarding the gender of their participants has shown that male prospective teachers (M=2.71) favoured more reform-oriented changes in their practice than female counterparts (M=2.61). On the other hand, Hripsime et al's (1994) research on beliefs about student-centered instruction revealed that female teachers' had more positive views on student-centered methods than male teachers. Similarly, Beck et al (2000) supported that females are more likely to implement a constructivism approach than men. But the findings of Isikoglu et al (2009) brought out the fact that regardless of gender, teachers favoured student-centered education in their practice. Consequently, the results of this study proposes that sex difference isn't obstacle for being reform-oriented teachers in science.

5.2 Conclusions and Implications of the study

In this study, firstly the levels of AE and BARSTL possessed by PTs were determined. Secondly, the demographic variables of PTs in terms of AE and BARSLT were investigated. The results of the study indicated that science PTs had considerably high awareness of AE and reformed beliefs in science education and showed that they were aligned with innovative movements in teaching and learning. The educational demands of the 21st century necessitate novel and out of the ordinary teaching practices which encourage solving complex problems, using technology and adapting to challenging situations (Bernhardt, 2015; Christenson, 2010; Friedman, 2007). Thus, workplaces are in need of teachers who can handle problems flexibly and adapt to reform movements in science. Teachers are the key elements in making the reform in science possible and creating the environment for students to analyse and discuss the problems by creating opportunities to thrive with the needs of the 21st century. Consequently, the current study provided some information about the levels of teachers' preparedness to embrace the upcoming situations and once again emphasizing the need for the development of AE skills and the reformed beliefs of PTs in teacher education programs.

Moreover, the study presented the findings about the effect of academic major, grade level, gender and work experience on AE and BARSTL of teacher candidates. When the results of academic major differences were observed for AE and BARSTL construct, it was concluded that no significant results were found. Regardless of their major, PTs demonstrated to have adequate levels of both dependent variables. By looking at this finding, it is important to stress out that the Faculty of Education in this public university provides a fair distribution of courses among majors by giving all science education departments an opportunity to experience the similar courses that contribute to their professional development. Likewise, the gender independent variable didn't show noteworthy distinctions between male and female PTs. Again, indicating no gap of learning opportunities for different groups. Although some studies represented one gender favouring reform movements more than other one (Karaman & Karaman , 2013; Hripsime et al., 1994; Beck et al., 2000), it is crucial to point out that gender inequalities in this study weren't encountered.

Additionally, the levels of years and work experience of participants were examined to see if the years improve PTs' beliefs and adaptiveness about reforms in science education. Because it was believed that with years teachers' views about change and improvement in their practices will take place (Guskey, 1986; Loucks-Horsley, Hewson & Stiles, 1998; Levitt, 2001; Crawford, 2005; Carbonell, 2014; Fairbanks et al., 2010). In the study, the grade level discrepancies were seen in the AE skills development over time. Senior PTs were more adaptive experts than their counterparts and showed significant levels of adaptiveness and innovativeness. Thus, the grade level of students proved to be developmental stairs through which prospective teachers move on to become more adaptive. However, the findings didn't indicate any change for reformed beliefs of teacher candidates between years. This means that seniors didn't differ in their beliefs with freshmen, sophomores and juniors. Even though it may seem to be good for beginning levels to have the same levels with seniors, for the latter ones this doesn't imply any satisfying results. Even if the beliefs didn't change completely, at least some minor changes should have been expected in higher level teacher candidates. Similarly, the experienced teachers who had professional teaching practices haven't been able to score higher than the ones who haven't experienced school environments. Here it is important to pay attention to the number of prospective teachers who could instruct at schools and the ones who couldn't. Thus, it is important for education institutions to encourage PTs involvement in professional development programs to achieve desired results.

The place of adaptive expertise is significant in teacher education and the recommendations to develop the skills shouldn't be underestimated. At the same time, it is important to make PTs aligned with the reformed movement in science. In the light of the findings of this study and previous studies on AE and BARSTL, the following suggestions can be proposed:

1. The higher education institutes can encourage the implementation of courses at universities which would enable students to pursue the newest trends in the field of education, in particular, methods and technological advancements.
2. Teacher educators should require prospective teachers to demonstrate the teaching or discuss the new curriculum promoting ways on how to deal with new topics.

3. The promotion and development of AE in science education is important (Crawford et al., 2005), thus teacher education programs should integrate the classes which enable PTs incorporate new findings in science into their instruction, implement new methods into their teaching and possess an effective assessment of what students know and can do.
4. Teacher adaptive expertise is developed slowly over time (Anthony et al., 2015), therefore it is crucial that teacher educators involve the beginning students to participate in efficient and novel solutions requiring practices. In order to achieve the desirable results, teacher educators should be adaptive experts themselves.
5. Teacher training programs can include novelty courses in which PTs will encounter unfamiliar situations and teacher candidates will explore these tasks, solve them on themselves and reflect on their weaknesses.
6. The university education should support a permeating constructivist paradigm to science education more than traditional approaches in science by designing the lessons aligned with reformed movement in science.

5.3 Recommendations for Further Studies

The current study suggests some propositions for further studies of AE and BARSTL in the field of education:

1. The further studies can be conducted in longitudinal design so that the development of AE and BARSTL can be observed in participants.
2. The current study was conducted in a public university with high-ranked Faculty of Education in Turkey, however to get a more general view of reformed beliefs and adaptiveness in science education, the further study can be conducted in other public and private universities of different regions of Turkey.

3. The sample consisted of PTs but further studies can include in-service teachers as well, to see in-service teachers' beliefs about reformed movement and adaptive skills in science education.
4. In the current study, only science education majors were included whereas in the following study all education department PTs can be involved in order to see the readiness of PTs embracing new trends in education.
5. In this study, the Likert type scale was used for both AE and BARSTL but in the future the qualitative method can be employed. By interview and observation, the factors affecting the development of AE and BARSTL can be defined.

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A. APPENDIX A

Permission from Ethical Committee

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

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02 Ocak 2020

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Dr. Gökhan ÖZTÜRK

Danışmanlığını yaptığınız **Alina KAZAKOVA'nın "Öğretmen Adaylarının Adaptif Uzmanlık ve Bilim Eğitim ve Öğretimine Yönelik Reform İnançları Arasındaki İlişkinin Araştırılması"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **517 ODTU 2019** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız

Doç.Dr. Mine MISIRLISOY

Başkan

Prof. Dr. Tolga CAN Üye	Doç.Dr. Pınar KAYGAN Üye
Dr. Öğr. Üyesi Ali Emre TURGUT Üye	Dr. Öğr. Üyesi Şerife SEVİNÇ Üye
Dr. Öğr. Üyesi Müge GÜNDÜZ Üye	Dr. Öğr. Üyesi Süreyya Özcan KABASAKAL Üye

B. APPENDIX B

AE questionnaire

		Strongly	Disagree	Slightly	Slightly	Agree	Strongly
		1	**2**	**3**	**4**	**5**	**6**
1.	I create several models of a problem to see which one I like best.	1	2	3	4	5	6
2.	As I learn, I question my understanding of the new information.	1	2	3	4	5	6
3.	I feel uncomfortable when I cannot solve difficult problems.	1	2	3	4	5	6
4.	Knowledge that exists today may be replaced with a new understanding tomorrow	1	2	3	4	5	6
5.	Usually there is one correct method in which to represent a problem.	1	2	3	4	5	6
6.	I often try to monitor my understanding of the problem.	1	2	3	4	5	6
7.	I am afraid to try tasks that I do not think I will do well.	1	2	3	4	5	6
8.	Most knowledge that exists in the world today will not change.	1	2	3	4	5	6
9.	When I consider a problem, I like to see how many different ways I can look at it.	1	2	3	4	5	6
10.	As a student, I cannot evaluate my own understanding of new material.	1	2	3	4	5	6
11.	Although I hate to admit it, I would rather do well in a class than learn a lot.	1	2	3	4	5	6
12.	Scientists are always revising their view of the world around them.	1	2	3	4	5	6
13.	I tend to focus on a particular model in which to solve a problem.	1	2	3	4	5	6
14.	I rarely monitor my own understanding while learning something new.	1	2	3	4	5	6
15.	One can increase their level of expertise in any area if they are willing to try.	1	2	3	4	5	6
16.	Facts that are taught to me in class must be true.	1	2	3	4	5	6
17.	I am open to changing my mind when confronted with an alternative viewpoint.	1	2	3	4	5	6

18.	When I know the material, I can recognize areas where my understanding is incomplete	1	2	3	4	5	6
19.	Expertise can be developed through hard work.	1	2	3	4	5	6
20.	Existing knowledge in the world seldom changes.	1	2	3	4	5	6
21.	I rarely consider other ideas after I have found the best answer.	1	2	3	4	5	6
22.	I have difficulty in determining how well I understand a topic.	1	2	3	4	5	6
23.	To become an expert in my field, you must have an innate talent for that field.	1	2	3	4	5	6
24.	Challenge stimulates me.	1	2	3	4	5	6
25.	I find additional ideas burdensome after I have found a way to solve the problem.	1	2	3	4	5	6
26.	I monitor my performance on a task.	1	2	3	4	5	6
27.	Experts in a field are born with a natural talent for their field.	1	2	3	4	5	6
28.	Scientific theory slowly develops as ideas are analyzed and debated.	1	2	3	4	5	6
29.	For a new situation, I consider a variety of approaches until one emerges superior.	1	2	3	4	5	6
30.	As I work, I ask myself how I am doing and seek out appropriate feedback.	1	2	3	4	5	6
31.	Experts are born, not made.	1	2	3	4	5	6
32.	Even if frustrated when working on a difficult problem, I can push on.	1	2	3	4	5	6
33.	Scientific knowledge is developed by a community of researchers.	1	2	3	4	5	6
34.	I solve all related problems in the same manner.	1	2	3	4	5	6
35.	Poorly completing a project is not a sign of a lack of intelligence.	1	2	3	4	5	6
36.	When I solve a new problem, I always try to use the same approach.	1	2	3	4	5	6
37.	Scientific knowledge is discovered by individuals.	1	2	3	4	5	6
38.	When I struggle, I wonder if I have the intelligence to succeed in my field.	1	2	3	4	5	6
39.	There is one best way to approach a problem.	1	2	3	4	5	6
40.	I seldom evaluate my performance on a task.	1	2	3	4	5	6
41.	I feel uncomfortable when unsure if I am doing a problem the right way.	1	2	3	4	5	6
42.	Progress in science is due mainly to the work of sole individuals.	1	2	3	4	5	6

APPENDIX C

BARSTL questionnaire

Appendix: The BARSTL Questionnaire

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

1. Students develop many ideas about how the world works before they ever study about science in school.	SD	D	A	SA
2. Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	SD	D	A	SA
3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	SD	D	A	SA
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	SD	D	A	SA
5. Frequently, students have difficulty learning scientific concepts in school because their ideas about how the world works are often resistant to change.	SD	D	A	SA
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	SD	D	A	SA
7. Students know very little about science before they learn it in school.	SD	D	A	SA
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	SD	D	A	SA

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	SD	D	A	SA
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	SD	D	A	SA
11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	SD	D	A	SA
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	SD	D	A	SA
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading, or a demonstration.	SD	D	A	SA
14. During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	SD	D	A	SA
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	SD	D	A	SA
16. Assessments in science classes should only be given after instruction is completed; that way, the teacher can determine if the students have learned the material covered in class.	SD	D	A	SA

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

17. Students should do most of the talking in science classrooms.	SD	D	A	SA
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	SD	D	A	SA
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	SD	D	A	SA
20. Teachers should allow students to help determine the direction and the focus of a lesson.	SD	D	A	SA
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	SD	D	A	SA
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	SD	D	A	SA
23. The teacher should motivate students to finish their work as quickly as possible.	SD	D	A	SA
24. Science teachers should primarily act as a resource person, working to support and enhance student investigations rather than explaining how things work.	SD	D	A	SA

The Nature of the Science Curriculum

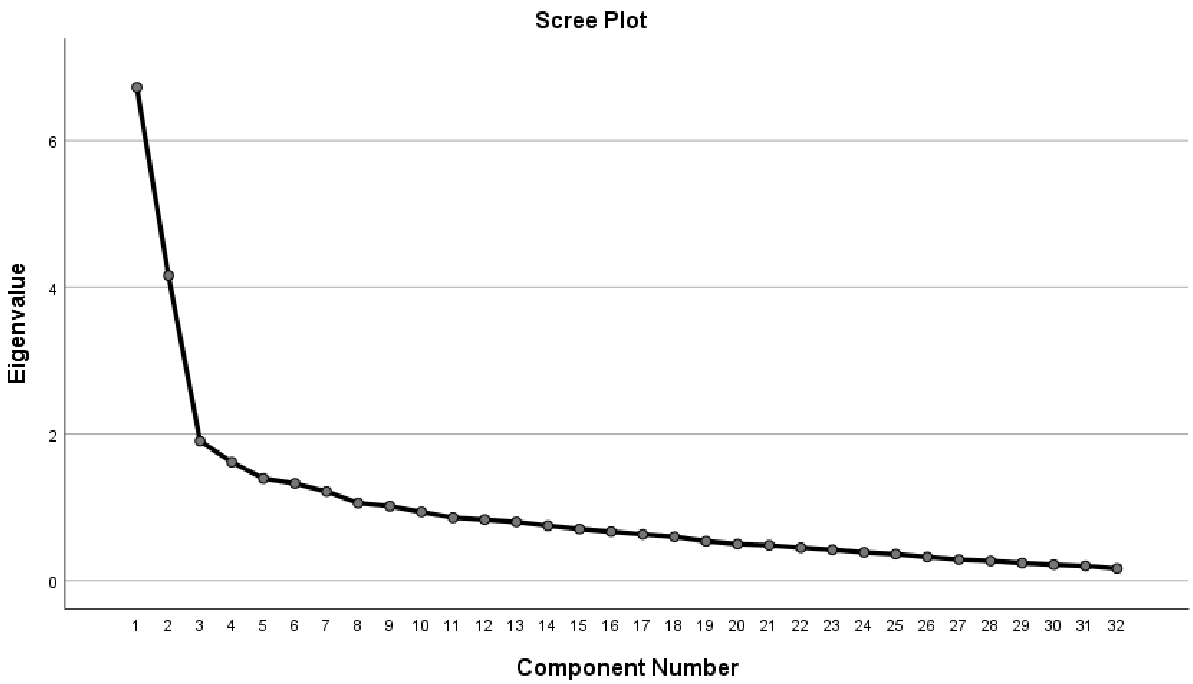
The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

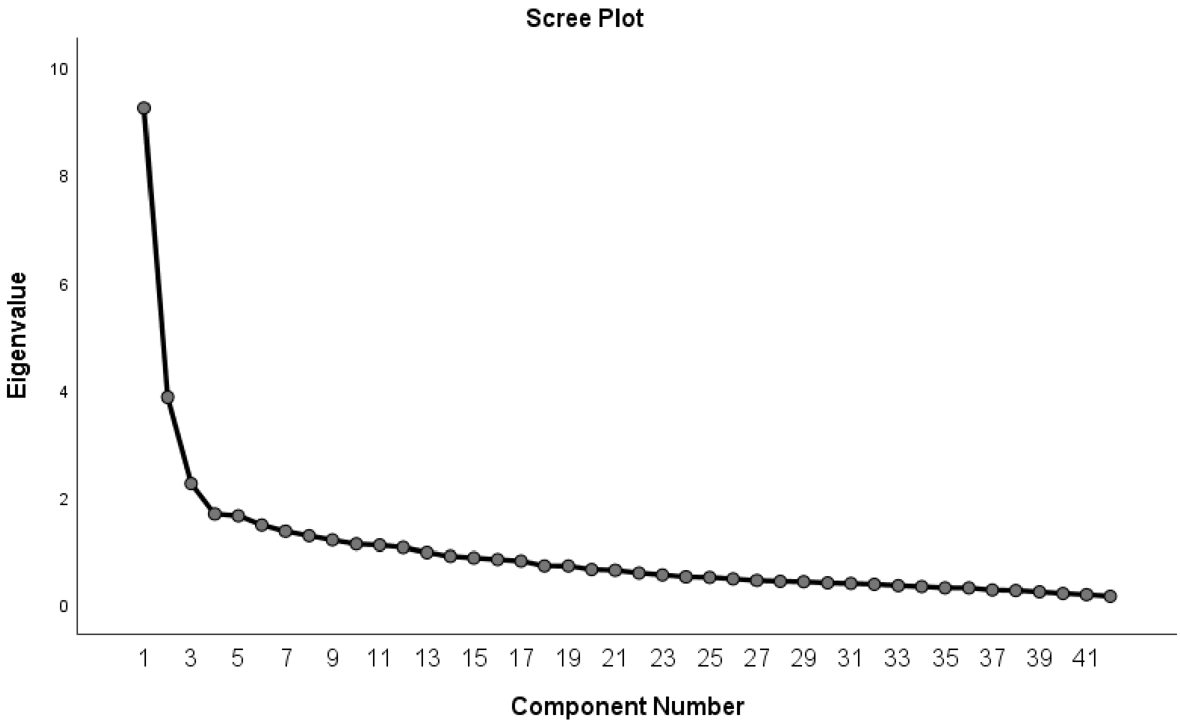
25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	SD	D	A	SA
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	SD	D	A	SA
27. Students should know that scientific knowledge is discovered using the scientific method.	SD	D	A	SA
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	SD	D	A	SA
29. In order to prepare students for future classes, college, or a career in science, the science curriculum should cover as many different topics as possible over the course of a school year.	SD	D	A	SA
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	SD	D	A	SA
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with "define the problem" and ends with "reporting the results."	SD	D	A	SA
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	SD	D	A	SA

APPENDIX D

BARSTL scree plot



AE scree plot



Principal Component Analysis of BARSTL

	C1	C2	C3	C4
barstl4	**.809**			
barstl6	**.791**			
barstl22	.703		**.304**	
barstl27	.688			
barstl12	.681			
barstl7	**.672**			
barstl25	.667			
barstl11	.622			
barstl9	.496			.320
barstl16	.465		.374	
barstl3	**.426**	.337		
barstl19		.688		
barstl30		.605		
barstl28		.597		
barstl14		**.594**		
barstl10		**.573**		
barstl21		.528	**.497**	
barstl8		.478		
barstl13		**.477**		
barstl20		.476		
barstl32		.476		
barstl24		.403		
barstl18			**.667**	
barstl15			.581	
barstl31			.537	**.314**
barstl23		.427	**.519**	
barstl17			-.477	.339
barstl29	.333		.431	
barstl1				.694
barstl5				.672
barstl26				**.503**
barstl2	**.331**			.462

Principal Component Analysis of AE

Items	C1	C2	C3	C4
adapt1	.330			**.632**
adapt2	**.444**			.665
adapt3		**.511**		
adapt4	.459		**.394**	.464
adapt5			.541	**.319**
adapt6	**.510**			.324
adapt7		**.565**		
adapt8	.411		**.517**	
adapt9	.537			**.436**
adapt10		.301	.522	
adapt11		**.540**		
adapt12	.503			
adapt13			.518	
adapt14		.326	.508	
adapt15	.445			.342
adapt16			**.469**	
adapt17	.546			
adapt18	**.547**			
adapt19	.443			.347
adapt20			**.542**	
adapt21		.491		
adapt22		.554		
adapt23		**.578**		.331
adapt24	.496	**.309**		
adapt25		.594		
adapt26	**.573**			.320
adapt27		**.493**		
adapt28	.625			
adapt29	.658			
adapt30	**.705**			
adapt31		**.410**	.404	
adapt32	.659			
adapt33	.527			
adapt34				**.500**
adapt35	.550			
adapt36				
adapt37	-.354		**.507**	
adapt38		**.658**		
adapt39			.580	

Items	C1	C2	C3	C4
adapt40		.478		.327
adapt41		**.648**		
adapt42				