Master thesis

Adaptive Expertise within the Technical Medicine curricula

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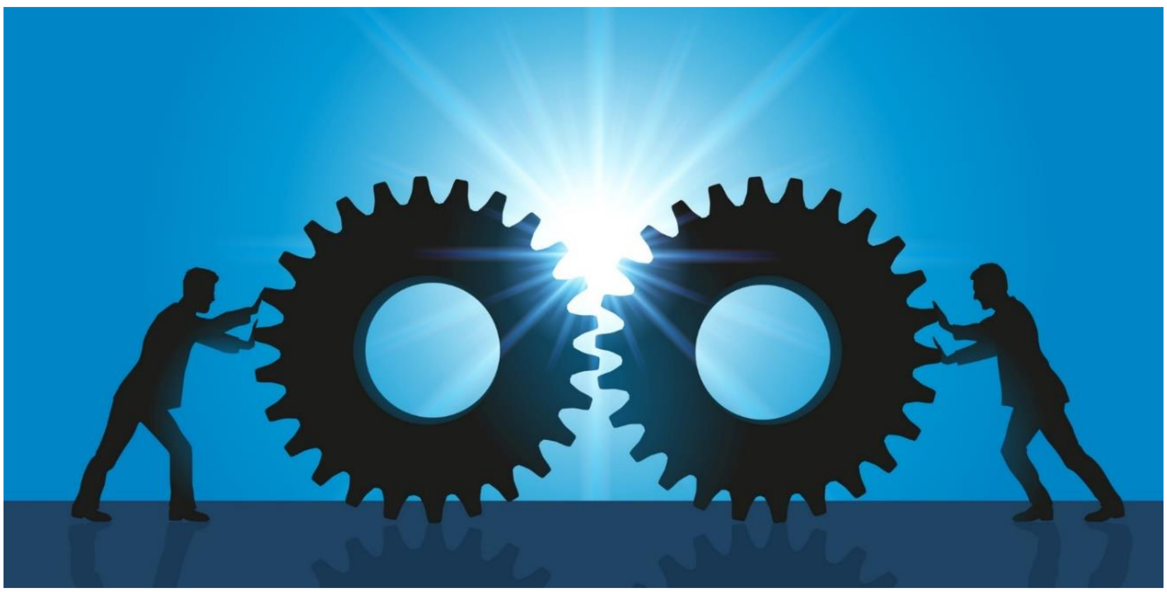

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It has been a long way and I cannot thank everyone who helped me through the past 11/12 years. But I am grateful for every one of you.

Time for the next chapter.

Summary

Background and Objective

As the world around us is developing at an ever-increasing pace, technology in healthcare is no different. To keep medical professionals well-informed and up-to-date,` universities, in this case, medical schools, are searching for ways to prepare their students for these challenges. The Technical Medicine program of the University of Twente has been developing its curriculum while aiming to give its students something more than regular courses: skills to become adaptive experts. Adaptive expertise is a broad construct that includes several cognitive, personality-related, and motivational aspects which enhance problem-solving. Doctors who have adaptive expertise skills, which are based on the following components: knowledge structures, metacognitive capabilities, and innovative skills are able to have a deeper understanding of their profession. Not just knowing what procedure works and how, but also why. Increasing their problem-solving skills and granting them the ability to be more flexible when helping their patient. For hospitals, organizational success depends on these future doctors. As a result, the subject of individual adaptability has been getting more attention in the medical field. Research on routine and adaptive expertise has already provided some insight on this matter. However, there are hardly any studies on how individual adaptability is applicable and trainable in medical studies. Considering the relevance of this topic, this study aims to contribute to filling this research gap and providing relevant insights for (future) students and research.

Methods and results

Our study focused on the development of adaptive expertise of Technical Medicine students throughout their first three years, following three cohorts. Additionally, we looked at the link between self-directed learning and adaptive expertise, as self-directed learning is closely linked with adaptive expertise. Because this study was conducted during the COVID pandemic and because of the potential sample size, we chose to

work with online questionnaires based on a tool developed by Carbonell et. al. (2016). Descriptive statistics, exploratory factor analysis, Kruskall-wallis test, Spearman’s rho test, and a Wilcoxon signed-rank test were used for analysis. We concluded there is no positive correlation between adaptive expertise and attending the Technical Medicine program for a longer period of time. Increases were found, however, in the separate areas of knowledge structures, metacognitive capabilities, and innovative skills. Additionally, we found a weak to moderate correlation between adaptive expertise and self-directed learning (r=.456). Lastly, we did not find a statistically significant relationship between participating in the multidisciplinary project, the Bachelor’s assignment, and growing adaptive expertise.

Discussion and conclusion

While our hypotheses were not confirmed, we saw several reasons to replicate our study and delve deeper into certain topics. Although we did not find a positive correlation between adaptive expertise and attending the Technical Medicine curriculum for a longer time we need to keep in mind we had a relatively small sample (n=114) and we used a quantitative approach due to the COVID pandemic, which may have influenced students’ responses as it was a self-reported questionnaire. When looking at the literature SDL and adaptive expertise seem closely linked but we only found a moderate correlation. We designed the questions related to SDL and adaptive expertise ourselves. This may have influenced the results in addition to the way we set up our research.

Other possible reasons for our results were discussed with several suggestions to improve our tool and the conducted research, assuring the prevention of biases and increasing validity and credibility. Additionally, recommendations considering the topics of self-directed learning and metacognitive capabilities, the multidisciplinary project, and the growth of the knowledge structures, metacognitive capabilities, and innovative skills components were suggested.

Chapter 1

1.1 Introduction

Experts are highly regarded and expected to possess a deep content of knowledge in their respective domains. These specialists are able to recognize patterns with ease, have control of their emotions and behavior, and are able to be thorough when self-evaluating (Chi, 2006 & Ericsson et al. 2006). And they need to be. At an ever-increasing pace, the world around us is changing. Over the last decades, technical developments and globalization have had an enormous impact on our way of living and learning, and this development does not seem to be slowing down. To keep up with a rapidly changing society, experts need to be able to adapt to their environments and have flexible thinking skills.

Medical professionals need to be well-informed and are expected to keep up with the rapidly developing technology in healthcare. The same applies to medical experts, and, by extension, students of medicine. According to Kramme (2007), the rate at which new medical technology is developed and implemented has never been higher. A study conducted by Deloitte about what skills future medical professionals should hold, confirms the importance of this flexibility. According to several hospital CEO’s, the ability to be innovative is of great importance for future doctors (Greenspun, Abrams & Kane, 2016). Hospitals no longer merely need doctors who are experts in their fields, they need doctors who are experts in their field and can, on top of that, easily adapt to the constantly changing world and environment. Slowly, the skillset of a future medical professional is changing.

To keep up with demand, universities, in this case, medical schools, are expected to anticipate these trends. While the development of skillsets has received increased attention, universities are criticized for not being able to produce graduates with abilities or expertise in innovation (The Conference Board of Canada, 2014). It is reasonable to expect universities to prepare their students to become experts with particular domain expertise and allow them to adapt to continuously learn and adapt to future challenges (Mylopoulos & Regehr, 2007; Drees, 2016).

Although ‘adaptability’ is a rather ambiguous construct that is applicable in various situations, there is a field of research that can give an understanding of individual adaptability, specifically, adaptive expertise (Nikolova, 2013). While expertise is described as the peak level of performance within a certain domain, Hatano and Inagaki (1986) conceptualized two forms of expertise: routine and adaptive expertise. A routine expert knows ‘how’ or ‘what’ works and can demonstrate common tasks within their domain with a certain level of skill. However, in contrast to an adaptive expert within the same domain, the routine expert may have difficulties adjusting to unfamiliar situations, decreasing their level of performance. The adaptive expert has a deeper conceptual understanding of the principles of why solutions work (knowledge structures). They do not only know ‘how’ or ‘what’ but also know ‘why’ solutions work. In addition, they have procedural knowledge, show analogical problem-solving skills and can be flexible when the circumstances require them to, transferring what they have learned to new situations (Groenier, 2017 & Kua, et al., 2020). Well-developed metacognitive capabilities help adaptive experts achieve this. They are able to reflect and monitor knowledge levels, available information, and the suitability of possible solutions while also exercising a high level of self-regulation (Nikolova, 2013 & Shin, et al., 2003). These traits are particularly relevant in health professions education, whereas adaptive expertise is essential for handling patients with more and more complex cases and age-related demands (Lim et al., 2017). As a result, adaptive expertise has become a worthwhile objective for curricula in the health professions education community (Martimianakis, Mylopoulos & Woods, 2020).

Although there is no cohesive conclusion about which characteristics are typical for adaptive expertise, the above-mentioned aspects – metacognitive capabilities, knowledge structures, and innovative skills are frequently linked to adaptive expertise

(Martin & Schwartz, 2009). One form of metacognitive ability is self-regulation. Self-regulation is a concept that shows many parallels with self-regulation in self-directed learning (SDL). Both constructs focus on active engagement, awareness, and goal-directed behavior but SDL also focuses on conscious development of learning goals and searching for fitting learning resources and strategies (Bolks & van der Klink, 2011), which are additional aspects of an adaptive expert (Karoly, 1993; Mylopoulos & Woods, 2009; Wineburg, 1998). While several studies have focused on self-regulated learning and adaptive expertise, no studies of SDL and adaptive expertise have been conducted, leaving a significant gap.

The University of Twente, located in the Netherlands, designed the Technical Medicine program, which was the first of its kind in the world. This program has an unparalleled focus on combining healthcare and technology, aiming at closing the gap between the development of high-tech medical technology and the expertise which is necessary to assure the safety of patients (Groenier, 2017). To assure students are prepared for the aforementioned topics, the program aims to train adaptive expertise by using diversified learning experiences, such as a simulation center, apprenticeships, and multidisciplinary projects. The curriculum aims to train Technical Physicians who demonstrate conscious competence: being able to self-regulate their knowledge and capabilities. SDL plays a large part in the bachelor's program curriculum as the students systematically reflect on not only task performance but also the student's problem-solving processes, receiving feedback from various subjects matter experts and peers (Groenier, 2017).

When examining studies on adaptive expertise and healthcare education, we can conclude there is more work to be done. Kua et al. (2020) conducted a scoping review and concluded that limited research currently exists on training adaptive expertise in health professions education. Looking at the crucial role of adaptive expertise in the training of health professionals in this period of social and technological change, more research on these topics is needed. The technical medicine bachelor program aims to train adaptive expertise and includes SDL in its curriculum, making it a meaningful sample to look at when studying both topics.

Therefore, this study will intend to further clarify the link between healthcare education and adaptive expertise and explore if there are existing links between adaptive expertise and self-directed learning.

Chapter 2

2.1 Theoretical Framework

Now that it is clear which factors are involved with answering the research question, they will need to be conceptualized. First, adaptive expertise will be reviewed. Secondly, self-directed learning (SDL) will be discussed, followed by the importance of measuring adaptive expertise. After several sections, we will present sub-questions and hypotheses which are related to our research question.

2.2 Adaptive Expertise

To grasp the essence of adaptive expertise, it is important to understand what expertise is. Research conducted on adaptive expertise originated from research on expertise. According to Holyoak (1991), it is a result of third-generation research on expertise.

What is expertise? The term ‘expert’ is derived from the same Latin verb as experience and experiment. These words refer to efforts to learn from experience. When a person is able to outperform ordinary people through presenting mastery of a particular subject, with special skills or knowledge through experience and instruction this person is recognized as an expert (Ericsson, 2008). Before an individual is able to reach an expert level of performance, he typically spends years gaining extensive experience in a particular domain. Expertise, in general, is defined as ‘expert skill or knowledge: the skill, knowledge or opinion possessed by an expert’, an individual is called an expert when he is very knowledgeable about or skillful in a certain area such as healthcare (Ericsson, 2008; Ericsson & Towne, 2010).

Early research on expertise tried to identify characteristics of expertise by comparing the performance of domain experts with that of novices while executing domain and non-domain-related assignments. The results showed that domain experts are not superior to novices when performing outside their domain (Ericsson & Kintsch, 1995; Nikolova, 2013). Consequently, studies were conducted to look for theories that could explain this phenomenon. As a result, Chase and Simon (1973) came up with the chunking theory and Gobet and Simon (1998) tried to explain this phenomenon with the template theory.

These theories showed that the expert's superior performances, in comparison with that of a novice in that particular domain, were based on the ability of the expert to compress and integrate 'chunks' of information which made them able to be faster and better in recognizing patterns among their domain-related assignments. There is evidence that people who are asked to perform memory tasks use their experience with reading to fill the slots from left to right, or from right to left if their native language is designed that way, to complete their tasks faster (Guida & Lavielle-Guida, 2014; Zebian, 2005).

The results of these studies showed that expertise in a domain depends on knowledge of the domain which is acquired through experience but even more on the organization of knowledge, with specific knowledge structures. Within the literature, there are several descriptions for these knowledge structures such as mind palaces, cognitive mapping, and cognitive schemas (Ericsson, 2006; Smith, et al., 1997). Scholars unanimously agree that the knowledge of experts and novices vary in three facets. In the first place, experts are more likely to have a large number of knowledge structures which include a larger quantity of attributes that are broader, deeper, and more developed which makes them faster, have a deeper understanding of the domain, and have better pattern recognition. Secondly, the experts' knowledge structures and their respective attributes are more connected in comparison with novices. An example of this is that experts have knowledge structures that integrate problem definitions and solutions, while novices are more likely to have two separate structures. Also, experts demonstrate more and better self-regulatory skills observing and evaluating their performance (Nikolova, 2013; Smith et al., 1997; Fiske & Taylor, 1991; Kimball & Holyoak, 2000; Glaser & Chi, 1988; Chi et al., 1988; Ericsson et al. 2006). The development and use of knowledge structures allow the domain experts to adapt and overcome task hindrances and to reach exceptional levels of performance. Examples are chess masters who are able to play games blindfolded (Ericsson, 2006), typists who are able to type words at a speed of approximately 75 words per minute (Lewandowsky, et al. 2007), or mister Akira Haraguchi who was able to memorize PI to 111,700 digits.

However, additional studies revealed that knowledge structures can be a hindrance for experts which makes them unable to adapt to novel tasks and even decrease performance. Findings of these studies implied that experts become accustomed to using their existing knowledge structures and may not be able to refrain from this automatic processing, which influences their adaptability (Sternberg & Frensch, 1992; Wiley, 1998). In the literature, this is called the ‘Einstellung’ effect. This phenomenon is described as the habit of people to apply previously learned strategies even when they are provided with a more feasible option that could be more efficient. According to Hatano and Inagaki (1986), this is called ‘routine expertise’, whereas the more progressive way of working is named ‘adaptive expertise’

Hatano and Inagaki (1986) were the first ones to introduce adaptive expertise and they made a distinction between routine and adaptive expertise. According to Hatano and Inagaki (1986), routine experts are accomplished in the domain in which they have automated their performances that enables them to solve common problems fast and accurately. Yet, Hatano and Inagaki (1986) suggest that routine experts are not able to adjust to unfamiliar situations which will decrease their level of performance. The underlying problem is that routine experts lack a deep conceptual understanding of their domain and the guiding principles needed to complete an assignment. Adaptive experts do have a deeper understanding of the principles behind the procedures they are carrying out. Adaptive experts know more than just the ‘know what’ and the ‘know-how, they also ‘know why’. This gives adaptive experts the chance to solve novel problems, react differently and be flexible when the circumstances require them to. Bohle Carbonell, Stalmeijer, Könings, Segers, and van Merriënboer (2014) describe adaptive expertise as the ability for individuals to excel while in changing conditions.

2.3 Conceptualizations of adaptive expertise

Adaptive expertise is a construct which includes several personality-related, cognitive and motivational facets. Usually, problem-solvers show adaptive expertise skills when they solve previously encountered situations and create new procedures for new tasks.

To do so, the expert needs to have a conceptual understanding of the task at hand which makes it possible to find new solutions to problems (Carr, 2019).

Hatano and Inagaki (1986) made a distinction between adaptive and routine expertise. Various conceptualizations of the relationship between both concepts have been suggested by some more recent authors. One example is Chi (2011), who suggests that adaptive expertise is a result of continuous learning efforts and links experts engaging in deliberate practice, known as elite experts, and adaptive expertise. Chi (2011) argues that both expert groups possess enough knowledge of the processes in their domain of expertise and thus are able to reassess their behavior in different situations. Both groups are able to apply their knowledge to understand and react differently to unfamiliar topics (Chi, 2011). Therefore, Chi (2011) suggests that adaptive expertise and routine expertise are, to some extent, linked. Another conceptualization summarizes adaptive expertise to embody more than creativity and innovation coupled with routine expertise. But, merely acts as a framework to be able to develop adaptive expertise (Paletz, et al., 2013).

Additionally, there is the more frequently-used distinction that conceptualizes adaptive expertise as a give-and-take between innovation and efficiency (Schwartz, Bransford & Sears, 2005). According to this theory, routine expertise is characterized by almost perfect efficiency, instantly diagnosing specific solutions to defined domain problems. While on the other hand, novices can provide creative solutions but lack domain knowledge. Adaptive experts have the necessary level of domain knowledge while also being able to consider alternatives. Routine expertise is based on learning to apply domain-specific strategies to particular circumstances, whereas adaptive experts show a deeper understanding by being able to recognize which strategies are applicable (Paletz, et al., 2013).

While Martin and Schwartz (2009) pointed out that there is a lack of academic work to confirm which characteristics are typical for adaptive expertise, as there is no existing framework that is supported by a significant part of the conducted studies. And there are differences between the above-mentioned characteristics and. There are three characteristics that are frequently linked to adaptive expertise - metacognitive capabilities, knowledge structures, and innovative skills (Chi, 2011; Paletz, et al., 2013; Crawford, et al. 2005; Griffin & Hesketh, 2003; Bohle Carbonell, et al., 2014).

2.4 Characteristics of adaptive expertise

2.4.1 Knowledge structures

Knowledge structures are a fundamental part of being an expert, according to Smith et. al. (1997), there are several definitions for knowledge structures such as cognitive maps, schemas and scripts. In general, it is about the organization of knowledge. This does not seem to be different for adaptive experts. Additionally, domain-specific knowledge is needed for being able to respond adaptively to unusual circumstances (Nikolova, 2013). To be able to do so, the adaptive expert needs to have the ability to conceptualize and understand why a certain solution would be successful where others would fail (Brophy, Hodge & Bransford, 2004). When choosing a solution, the adaptive expert should be able to explain what he is doing but also why he is proceeding that way, while considering other options. Being able to explain why a certain procedure works are often described as conceptual knowledge and are essential for skills transfer and the development of expertise, generalizing principles that surpass certain contexts of a task (Cheung, Kulasegaram, Woods & Brydges, 2019). By doing so, the person participating will create meaningful connections about the domain at hand and this will lead to the creation of domain and conceptual knowledge and understanding.

According to empirical findings of Shin, Jonassen and McGee (2003), domain knowledge is a significant indicator for solving well-structured and ill-structured problems. Well-structured problems are well-defined problems with often well-known solution(s). Whereas ill-structured problems have unclear goals, possibly multiple solutions, incomplete information, and cannot be solved by general rules or principles. Because of these factors, ill-structured problems can be linked to adaptive experts as they have a conceptual understanding which enables them to look beyond the scope of the routine experts. Adaptive experts are more flexible and should be able to adapt to unknown situations and recognize viable opportunities and alternatives when confronted with unfamiliar situations (Brophy et al., 2004; Joung, Hesketh & Neal, 2006; Hatano & Inagaki, 1986). Based on these findings it is safe to assume that domain knowledge is an important factor of adaptive expertise. But, besides properly developed domain knowledge, adaptive experts require metacognitive capabilities to overcome their automatic routines, recognizing more than one solution for their problem(s).

2.4.2 Metacognitive capabilities

As mentioned before, in addition to the facets of routine expertise, adaptive expertise is characterized by cognitive and metacognitive capabilities (Crawford, 2007; Mylopoulos & Woods, 2009). Metacognitive capabilities include the ability to reflect and monitor knowledge levels, available information, and the suitability of possible solutions (Shin, et al., 2003). According to Ivancic and Hesketh (2002), being able to be flexible with these processes is critical for applying existing knowledge to novel problems. Being able to reflect on situations is an essential aspect of conceptual understanding (Chi, 2011), which in turn defines adaptive expertise. Experts who have the ability to reflect on their current level of knowledge, their domain-related learning needs, task demands and are able to transfer these into learning goals are what allows them to become adaptive experts (Chi, 2011). As asserted by Brophy, et al. (2004) this enables the experts to evaluate which part of their domain-related knowledge is suitable for the new problem and how missing knowledge can be attained. On the other hand, this gives them the chance to understand how new situations relate to previous situations which will give them the opportunity to learn from experiences.

Another metacognitive aspect that is often identified as essential for adaptive expertise is self-regulation (Nikolova, 2013). According to Karoly (1993), self-regulation is a process that enables people to guide their goal-directed activities over time and in changing circumstances. It calls for performance monitoring which also enhances learning as such processes improve cognitive mechanisms. Additionally, self-regulation contains the ability to acknowledge knowledge deficiencies and evaluate a student's problem-solving process (Mylopoulos & Woods, 2009; Wineburg, 1998).

2.4.3 Innovative skills

Another aspect recognized by researchers is the innovative skills of adaptive experts, otherwise known as behavioral adaptability (Griffin & Hesketh, 2003). Adaptive experts possess a certain frame of mind and attitude; they adjust their behavior when handling novel circumstances. Adaptive experts effectively distinguish between past knowledge and required knowledge when facing a novel or unexpected problem (Wineburg, 1998). Because of this flexibility, adaptive experts are able to adapt and oversee the situation and create multiple solutions for the situation at hand instead of picking a one-fits-all solution (Crawford, et al., 2005; Mylopoulos & Woods, 2009). They do so by looking at the bigger picture through the available data and evidence while staying open-minded and not taking their conclusions for granted (Crawford, 2007). Also, they are aware that their domain knowledge is dynamic and they are required to put in the effort and show a willingness for continuous learning (Fazey, et al., 2007; Fisher & Peterson, 2001).

To stay an adaptive expert, you need to be willing to participate in a lifelong learning cycle. Professionals that are willing to participate in challenging learning experiences and, while doing so, acquire new knowledge, will be able to reprogram previous schemas, keep adapting, and avoid the 'Einstellung' effect (Nikolova, 2013). To know how we will look in to ways to develop adaptive expertise.

2.5 Developing adaptive expertise

Mylopoulos, Kulasegaram & Woods (2018) argue that to become an adaptive expert variation in experience is essential. Conducted studies in both theoretical and empirical research support this claim. It has been theorized that when one is experiencing diversified learning this can stimulate the development of extracting general principles, conceptualizing and interpreting environments and the ability to transfer previous learning to the current topic (Dries, Vantilborgh, & Pepermans, 2012; Karaevli & Hall, 2006). Additionally, several studies hypothesize that diversified learning experiences are necessary as these experiences support the likelihood of adaption and increase the probability of one's individual behavioral adjustments, also called flexibility (Dawis & Lofquist, 1984; Griffin & Hesketh, 2003).

Other fields of research that suggest that diversified learning experiences could be advantageous for developing adaptive expertise are cognitive psychology and problem-solving. These studies argue that diversified learning experiences are beneficial for obtaining new cognitive abilities and different (new) knowledge structures, giving the opportunity to solve problems more efficiently (Huckman & Staats, 2011; Prahalad & Bettis, 1986). Furthermore, diversified learning experiences assure the learner experiences a more varied curriculum. Therefore, there is a smaller degree of similarities between previous and current learning experiences. As a result, experts are more likely to employ their conceptual problem understanding and look at several alternatives before using familiar solutions (Nikolova, 2013).

The field of education and training often points out the importance of variety in learning. It has been advocated that adaptability can be trained, if individuals get the chance to practice their skills in diverse situations that are in need of adaptability (Fazey, et al., 2007; Mueller-Hanson, et al., 2005; Nelson, Zaccaro, & Herman, 2010). According to Schwartz et al., (2005) individuals who get familiar with change-related activities are able to get different perspectives and enrich their experiences. As a result, these individuals are able to use these skills to better understand, and deal with, novel and unexpected situations. However, it is more likely that extensive life experiences such as experience through career affect the development of adaptive expertise more than training environments (Barnett & Kowalski, 2002).

Empirical research conducted by Pulakos et al. (2002) supports these indications. Their study focused on the effect of past diversified learning on adaptive expertise and they found a significant correlation between past experience and adaptive performance within their population. Additionally, based on several cross-sectional studies there is evidence that indicates that adaptive experts may have had more different kinds of experiences in comparison with routine experts (Nikolova, 2013). Therefore, Martin & Schwartz (2009) indicate that when one has engaged in adaptive behavior they can experience and learn the benefits of such behavior. This suggests that a diversified learning experience needs adaptive behavior and therefore can stimulate the development of adaptive expertise. As a result Martin et al. (2006), suggest that when routine experts are provided with the same amount of varied experiences they also have the ability to become adaptive experts.

When looking at these studies it is safe to assume there is a strong correlation between a highly diversified curriculum and the development of adaptive expertise. Based on the literature there are three types of diversified learning experiences which are mainly named for being able to facilitate the development of adaptive expertise: on-the-job diversified experience, task and career variety and formal education (Nikolova, 2013). As a result, we formulated the following sub-questions and hypotheses:

Sub-question: Is there a relation between adaptive expertise and attending the Technical Medicine bachelor program? Does the level of adaptive expertise from the technical medicine students increase every year they attend university?

Hypothesis: There is a positive correlation between adaptive expertise and following a Technical Medicine bachelor program.

Sub-question: Is there a relationship between adaptive expertise and participating in multidisciplinary projects? Are technical medicine students growing their adaptive expertise during their Bachelor’s thesis?

Hypothesis: There is a positive relationship between adaptive expertise and participating in a multidisciplinary project.

2.6 Measuring adaptive expertise

Being able to measure adaptive expertise is highly valuable for certain organizations and environments, as it allows them to identify, train and develop adaptive experts (Nikolova, 2013). Remarkably, most of the studies that measure adaptive expertise are empirical studies that focus on either the population being a routine or an adaptive expert, rarely looking at both (e.g. Crawford, 2007; Crawford et al., 2005; Wineburg, 1998). When looking at workplace literature there are several instruments that focus on some aspects of adaptability on the job but do not measure adaptive expertise as a whole (Bohle Carbonell et al., 2014). One example is van der Heijden’s instrument measures expert performance (2000). He addresses the dimension of expertise but according to van der Heijden (2000) meeting and surpassing achievement standards is of absolute importance for experts. This view obstructs the acquisition of new knowledge and skills, which are essential for developing adaptive expertise (Hatano & Inagaki, 1986).

As for subjective measuring methods for the concept ‘adaptive expertise’, there is a shortage of valid and universally available instruments. Subjective measurement methods are often used to research adaptive performance. These, however, have their limitations because they do not measure cognitive- and metacognitive capabilities and lack psychometrically sound scales (Charbonnier-Voirin & Roussel, 2012). Having an instrument to measure adaptive expertise is of utmost importance because is it an essential factor to predict adaptive expertise, thus being able to train it.

According to Bohle Carbonell et al. (2016), the instruments developed by van der Heijden (2000) and Fisher and Peterson (2001) provided the closest validation of the concept of adaptive expertise. As a result, Bohle Carbonell et al. (2016) used these two instruments as a basis to develop their instrument and validated such as feasible in measuring adaptive expertise. Bohle Carbonell et al. (2016) reported that knowledge structures and innovative skills are factors influencing adaptive expertise and have been validated through studies conducted among several professionals. Additionally, several studies reported that metacognitive capabilities are fundamental to the process of recognizing and evaluating actual concepts. These actions are crucial for reconstructing and reprogramming new knowledge and skills which are necessary for creating innovative approaches during problems and new situations. The use of this metacognitive approach has been proven to be vital when developing adaptive expertise according to recent studies (Mees et al., 2020; Gunstone & Mitchell, 2005; McKenna, 2014). Additionally, according to Griffin and Hesketh (2003), one of the key components of adaptive expertise is behavioral adaptability. To be able to stay an adaptive expert, the person, or doctor, in this case, needs to be able to keep challenging himself with new learning experiences and acquire new knowledge.

2.7 Self-directed learning

To be able to train medical professionals who demonstrate conscious competence and adaptive expertise, professionals who know the importance of their knowledge, skills, and capabilities in their respected field, self-directed learning (SDL) can be a beneficial learning method (Groenier, Pieters & Miedema, 2017). SDL allows people to increase their knowledge by setting goals, exploring ways to achieve them, discovering and developing individual solutions and strategies in formal and informal learning settings (Loyens, Magda & Rikers, 2008).

Formal learning is often directed by organizations, while informal learning regularly depends on the individual’s mindset and skills, which they use to define their learning. SDL is a promising concept that could enhance the individuality of a person’s learning (Marsick & Volpe, 1999). SDL is a learning form that incorporates active engagement and goal-directed behavior of the learner. Metacognitive skills and intrinsic motivation are essential (Loyens, Magda & Rikers, 2008). There is no universal definition for SDL as it is a versatile concept with different conceptualizations (Ellinger, 2004). Initially, SDL was seen as a personal trait and was only applied in adult education. It was assumed that when the learner became more mature, he automatically became more self-aware and self-directed. Knowles (1975), stated that SDL would be useful for students. Eventually, researchers looked at SDL as a learning state and it was conceptualized as a process that resulted in studies to better understand SDL as a form of learning (Ellinger, 2004). Although there is a relationship between personality traits and the occurrence of SDL which are influenced by situational circumstances, adult learners do not always show SDL behavior (Merriënboer et. al., 2014). SDL has many parallels with the concept of self-regulated learning (SRL) with the vital role of metacognition as a mutual factor (Loyens, Magda & Rikers, 2008; Pilling-Cormick & Garrison, 2007). Although both SDL and SRL are based on active engagement, awareness, and goal-directed behavior SDL fits this study better. SDL includes every aspect of SRL but also focuses on the conscious development of learning goals and choosing fitting learning resources and strategies (Bolks & van der Klink, 2011). Being able to guide your own goal-directed activities in changing circumstances is essential for growing adaptive expertise (Karoly, 1993; Mylopoulos & Woods, 2009; Wineburg, 1998). Therefore, SDL will be a part of this study.

SDL as a process has been defined by Knowles (1975) as “…a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes” (1975, p. 18; as cited in Ellinger, 2004). Based on this definition Ellinger (2004) identified five facets. Awareness of these five facets of SDL and taking initiative regarding these facets are of vital order to engage in SDL (Zimmerman et. al., 2000; Knowles, 1975).

The first facet of SDL is being able to *diagnose learning needs*. The learner should be able to recognize what they will or should learn. When a person feels a need to learn, the motivation to learn is higher than when an external party wants you to learn something (Knowles, 1975). Being able to self-diagnose learning needs is essential for healthcare professionals as they should be aware of their developing work environment (Kläser, 2018).

Formulating learning goals is the second facet. Being able to formulate learning goals that fit the learning needs involves critical thinking. The learner needs to be able to formulate goals that are relevant to the identified learning needs in the context of his education (Patterson, Crooks & Lunyk-Child, 2002). When the learner is able to formulate specific and proximal goals this likely improves the learner's motivation which results in enhanced learning and a performance boost (Schunk, 1990).

Identifying human and material resources for learning is the third facet of SDL. After diagnosing and formulating learning goals, the resources for learning must be identified. Human resources are people who could assist in the process of learning, such as managers or colleagues. Learning resources could be anything from a book to a complete E-learning module, depending on the goals. Learners should be aware of the possibilities within their environment and choose resources that fit the identified goals (Kläser, 2018).

Being able to choose and implement appropriate learning strategies. For the learner, it is highly important to be aware of learning strategies. They also need to have a clear understanding of their goals, needs, and resources to choose appropriate strategies that will aid them. Learning strategies include self-consequences, elaboration, seeking and selecting information, monitoring, and social assistance (Weinstein, Human & Dierking, 2000; Zimmerman & Pons, 1986).

The last facet of SDL is *Evaluating learning outcomes.* The emphasis lies on self-evaluation, which involves awareness and insight into the complete learning process (Knowles, 1975). Self-evaluation is described as the ability to judge one's performance in comparison with the chosen standard. Self-evaluation is a significant asset as it defines whether the learner has been successful in completing his goal or not. The valuation of performance is based on various criteria. Whether the learner succeeded or failed can be attributed to different causes, which will influence the subsequent response of the learners (Cleary, Callan & Zimmerman, 2012).

When looking at SDL from a process perspective, SDL can be perceived as a learning method. This indicates that the SDL process can be affected by its environment. Thus, it is significant to learn to which extent SDL can be influenced by external factors.

2.7.1 Factors influencing SDL

Now that the benefits of SDL have been explained, it is important to know the factors that can stimulate and influence SDL. According to Raemdonck et al., (2012) influencing factors can be categorized into two factors: personal and organizational. Personal factors such as past learning experiences, cognitive skills, personality, social-economic background, and attained competencies are related to SDL (Poell et al., 2004). Additionally, intrinsic motivation, goal setting, and career happiness have a positive influence on SDL. On the other hand, complications with self-reflection, goal setting, and implementing plans could be experienced as hindrances (Raemdonck, 2009; van Houten-Schat et al., 2018).

Organizational factors are relevant for organizations that are interested in stimulating SDL. Knowledge about SDL could be beneficial for organizations to shape students, employees, and organizational culture. Personal factors are harder to translate to practical interventions whereas organizational factors such as task variance and development opportunities are easier to implement (Raemdonck, 2009; Poell et al., 2004). According to Raemdonck, Gijbels and van Groen (2014), having the physical and mental demands of a job is also one of the predictors of to which extent a person will participate in work-related learning activities. In healthcare environments, patient contact is often one of the stimulating factors of SDL, whereas time-pressure activities function as a barrier (van Houten-Schat et al., 2018).

In addition, Raemdonck (2006) refers to SDL as an adaptive characteristic that helps students to achieve their goals. Characteristic refers to the personal factors of the student and adaptive refers to the reaction to the requirements and possibilities offered by the organization. This adaptive characteristic helps the student to deal with the learning process which will result in the achievement of his goals, such as mastery of a new skill or updating knowledge (Raemdonck et al., 2012).

When looking at the facets of adaptive expertise and SDL we can conclude that they are closely linked. Examples are diagnosing and evaluating learning needs and outcomes which require metacognitive abilities such as acknowledging knowledge decencies and the ability to reflect. Also, being able to choose and implement appropriate learning strategies asks for innovative skills like being flexible and looking for the bigger picture.

Therefore it is plausible that students who have SDL skills will score better on adaptive expertise. Therefore, we formulated the following sub-question and hypothesis.

Sub-question: Is there a relationship between adaptive expertise and SDL? Do technical medicine students who claim to have SDL skills score better on adaptive expertise than their peers?

Hypotheses: There is a positive correlation between adaptive expertise and self-directed learning skills.

2.8 Summary, research question(s), hypothesizes

As described previously, the development of adaptive expertise among future doctors is important, as healthcare is rapidly changing and gaining complexity. These current developments in healthcare require future doctors to have knowledge and skills of medicine, a life-long learning mentality, and self-directed learning skills. For this research, we will focus on various cohorts within the Technical Medicine bachelor course. Students who have been with the program for a longer time than their peers have participated in more novel situations and different learnings tasks and should be able to show a higher level of adaptive expertise, thus proving that the educational interventions that are part of the Technical Medicine curriculum increase the adaptive expertise of these future doctors. Also, we will follow a group of bachelor students who are working on their bachelor projects. At the start of this multidisciplinary project, we will send them a questionnaire, and after they finish it. The goal is to look for an increase in their adaptive expertise score.

Additionally, we examine the amount of SDL the students claim to apply. Do students who self-report using SDL more often score higher than their peers on the adaptive expertise scale? Even though the literature on adaptive expertise focuses on three main dimensions: knowledge structures, metacognitive capabilities, and innovative skills there seems to be a connection with SDL. Therefore, we will search for a link between adaptive expertise and SDL. However, first, we need to test and validate the measurement tool as it has been tested and validated on some occasions but not for this population. As a result, the research question and the sub-questions have been formulated as follows:

Research question: To what extent are technical medicine students developing adaptive expertise throughout their Bachelor's program and to what extent is the student's level of self-directed learning positively related to adaptive expertise?

Sub-question 1: Is there a relationship between adaptive expertise and attending the Technical Medicine program? Does the level of adaptive expertise from the technical medicine students increase every year they attend university?

Sub-question 2: Is there a relationship between adaptive expertise and SDL? Do technical medicine students who claim to have SDL skills score better on adaptive expertise than their peers?

Sub-question 3: Is there a relationship between adaptive expertise and multidisciplinary projects? Are technical medicine students enhancing their adaptive expertise during their Bachelor's thesis?

Chapter 3

Methods

3.1 Research design

This study was conducted during the COVID pandemic which made it unfeasible to interact with the participants through qualitative research methods such as observations and interviews. Additionally, our population consisted of at least three study-cohorts which concluded about 400 students and possible participants (students who did not advance to the Master's program nominal were also included). For these reasons we looked into quantitative methods to be able to answer our research question and sub-questions about adaptive expertise and self-directed learning within the technical medicine program, because of the potential sample size, we concluded that a questionnaire would be the best fit.

The questionnaire we used was a modified version of an adaptive expertise measuring tool developed by Carbonell et al. (2016). They created their tool based on several existing instruments. Carbonell et al. (2016) drew items from the scales 'metacognitive skills' and 'growth and flexibility of the instrument created by van der Heijden (2000). These were used as subscales of metacognitive skills and innovative capacities. The instrument of Fisher and Peterson (2001) was used to draw items from the scales 'multiple perspectives and metacognitive self-assessment. The total of items initially grew to 41 and to order them they were categorized into the following dimensions: domain-specific skills, metacognitive skills, and innovative skills. To decrease the length of the instrument they removed seventeen items because they did not fit the concept of adaptive expertise or were redundant. In the end, after analyzing for ease of understanding and uniqueness, the instrument contained seventeen items of which 5 tapped into domain-specific skills, 4 into metacognitive skills, and 8 captured innovative skills. The questionnaire had a 5-point Likert scale with a range from 'strongly disagree' to 'strongly agree' for all items. This served as a foundation for our questionnaire.

To ensure the questionnaire was sufficient for our research, we modified it. Firstly, we translated the questionnaire from English to Dutch as the Technical Medicine study is a Dutch study with only Dutch-speaking students. Secondly, we adjusted the existing seventeen items to better fit our research without losing the original meaning, associating questions with Technical Medicine. Thirdly, we changed the domain names based on our desk research: ‘domain-specific skills’ became ‘knowledge structures’, we changed ‘metacognitive skills’ to ‘metacognitive capabilities’. The term innovative skills, in contrast, remained intact. These domains are focused on adaptive expertise and were used for sub-questions one, two, and four of our main study.

To be able to answer sub-question two, which focused on adaptive expertise and SDL, we added one more domain (self-directed learning) and four more questions. These questions were based on the five facets of SDL identified by Ellinger (2004). Finally, all items were analyzed for the last time and discussed with a senior researcher experienced in expertise literature. After a slight modification, the questionnaire consisted of twenty-one multiple-choice questions and four general questions. Afterwards, our version was pilot tested using three Technical Medicine students. The three students filled in the questionnaire without any problems nor additional questions. As a result, we deemed our questionnaire as sufficient (Appendix 3).

To complete the questionnaire, we added one question asking for consent to use the data of our participants, in accordance with the Behavioural Management and Social Sciences (BMS) Faculty of the University Twente, and added three demographic questions about student numbers, gender, and in which cohort they started their study. The questionnaire was put into Qualtrics, a web-based survey tool.

Technical medicine curriculum

As technology took an increasingly central role in the world of healthcare, healthcare professionals could no longer depend solely on monodisciplinary skills and knowledge, therefore, a new curriculum was developed. The goal of this curriculum was to educate future healthcare professionals who could understand and translate medical technology to enhance patient-specific procedures. Resulting in the technical medicine program and a new healthcare profession: the Technical Physician (Groenier & Miedema, 2020).

The designers used the model by Gustafson (2002) to develop the curriculum. This model includes analysis, design, implementation, and evaluation phases. A needs assessment was conducted including interviews and a literature review. Based on the results of this assessment, the professional profile was developed. It specified that:

"*A Technical Physician is a health care specialist who is competent in medical subjects, specific engineering and computer science subjects and is able to integrate these domains for adequate diagnosis and treatment in a health care setting. The Technical Medical domain concerns the analysis and identification of medical problems that results in the design and implementation of a solution for these problems based on knowledge of and insight into pathophysiological and technological concepts.*" (Groenier, Pieters & Miedema, 2017).

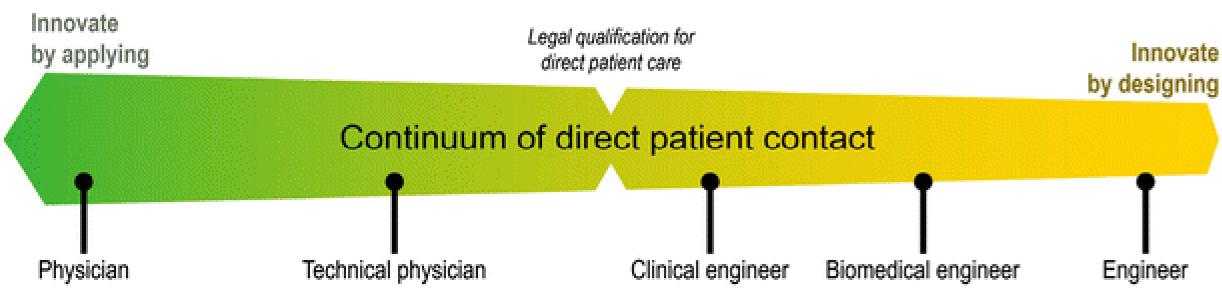


Fig 1. The position of a Technical Physician within the healthcare sphere. (from Groenier et al., 2017)

The literature review on adaptive expertise and the research-based design form the foundation of this professional profile (Groenier, Pieters & Miedema, 2017). Additionally, three instructional principles were selected based on the literature review:

Cognitive integration

The curriculum aims to stimulate the conceptual understanding of the students, not just knowing how technology and the human body function, but also why they function the way they do. Knowing why something functions a certain way relates to the student's conceptual knowledge, creating structured knowledge which is closely linked with adaptive expertise and fosters the lifelong learning mentality (Groenier, Pieters & Miedema, 2017; Lisk et al. 2016).

Self-directed learning

Another goal of the curriculum is to develop students into professionals who demonstrate conscious competence; professionals who are acquainted with their strengths and weaknesses in a healthcare setting. Self-directed learning contributes to this goal and is a way of learning which stimulates adaptive expertise (Carbonell et. al, 2016).

(Technical Medical) design projects

According to Carbonell et. al. (2016), it is of great importance to confront students with novel situations and learning tasks to develop their adaptive expertise. The curriculum is designed to assure students embrace a specific technical medical problem-solving strategy, based on the components of adaptive expertise and research-based design (Groenier, Pieters & Miedema, 2017).

Curriculum structure

The curriculum spans six years, reflecting the Dutch medical curriculum of three bachelor years and three master years. Fig 2.

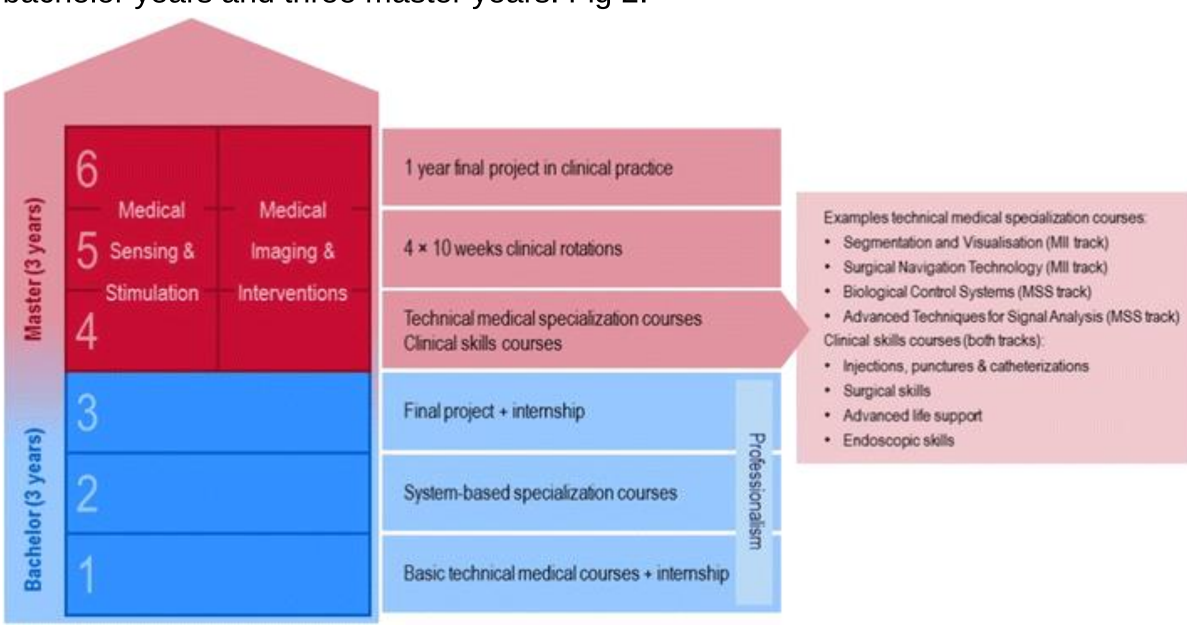


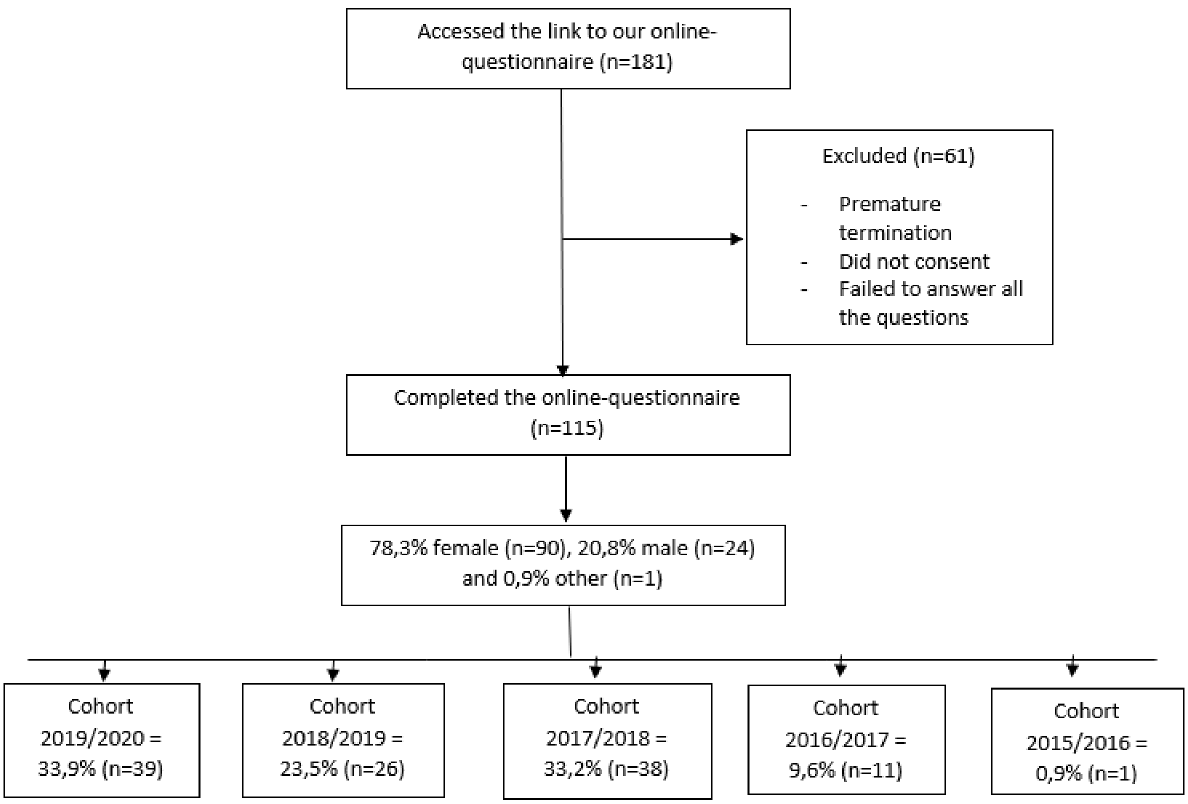
Fig. 2. Structure of the complete Technical Medicine Curriculum (from Groenier et al., 2017)

According to the literature, there are several ways educational programs for complex domains, such as healthcare, can stimulate the growth of adaptive expertise. The program contains several educational components such as open learning tasks, simulated task environments, and variability of skills creating a diversified learning program (van Merriënboer, 1997; van Merriënboer, Jelsma, & Paas, 1992; Van Merriënboer & Kirschner, 2018). The Technical Medicine bachelor program contains several of these educational components. More specific, the multidisciplinary project of the bachelor program is designed to accommodate several of these tasks

Participants

Data were collected from the student population of the bachelor Technical Medicine program of the University of Twente. The questionnaire was disseminated through the internal database from the Technical Medicine bachelor program consisting of first, second, and third-year bachelor students. According to the latest data, the program had 438 bachelor students in 2019. This resulted in 181 students accessing the link which is about 41,3% of the complete student population.

Fig. 3. Flowchart participants



In the end, we decided to cut the one participant from cohort 2015/2016 as this one person did not impact our study, ending with N=114.

3.2 Procedure

At first, before the questionnaire was disseminated through the internal database, all the bachelor students received an e-mail explaining the purpose of the study, and the reassurance of confidentiality was stated. Participation was completely voluntary and participants could withdraw from the study at any given time. Secondly, on the 5th of June 2020, all the bachelor students received their first invitation and on the 22nd of June 2020, they received a reminder. On the 29th of June 2020, the Bachelor students who participated in the multidisciplinary Bachelor thesis assignments received an invitation to fill out the questionnaire again and received a reminder 7th of July 2020. After cleaning up the data sets 19 Bachelor thesis students completed the questionnaire twice.

3.2.1 Data preparation

After receiving all the filled-in questionnaires, we started to clean our data sets in Excel. The first step in this process was to identify and remove inaccurate answers, unfinished and unreliable questionnaires. After cleaning, the datasets were consistent with each other and ready to be recoded for SPSS. The second step was to recode the student numbers from the bachelor thesis students to a nominal scale to be able to compare them when analyzing the data, numbering them from S1 to S19. Subsequently, the gender and cohort variables were recoded to an ordinal scale. Thirdly, the answers of the students were recoded to an ordinal scale with a 5-point Likert scale with a range from ‘strongly disagree’ to ‘strongly agree’ for all items just as the Carbonell et al. (2016) questionnaire. Lastly, when we completed the cleaning and recoding, we had a senior researcher check our data sets. After some small adjustments, we had three separate data sets to analyze. We started with the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Barlett’s test of sphericity to check the validity and reliability of our questionnaire.

3.3 Methods of analysis

To be able to answer all the sub-questions of our research we first needed to validate our measurement tool. To test this, we used the KMO and Barlett's Test and an Exploratory Factor Analysis.

KMO and Barlett's Test

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is a test conducted to examine the strength of the partial correlation between the chosen variables: knowledge structures, metacognitive capabilities, and innovative skills. Values closer to 1.0 are considered marvelous while values under 0.5 are deemed unacceptable. When your variables score a KMO value of .821, this indicates that there is a strong partial correlation. This makes it plausible to conduct a factor analysis. (Field, 2013).

Barlett's test of Sphericity compares an observed correlation to the identity matrix. It checks for redundancy between the chosen variables. This test is frequently performed before using a data reduction technique such as exploratory factor analysis. It is used to verify that a data reduction technique is feasible and able to compress data in a purposeful way (Field, 2013).

Exploratory Factor Analysis

The tool designed by Carbonell et al. (2016), which was a template for this study, has been used and validated on several occasions but not with this population (Carbonell et al., 2016; Mees et al., 2020; Nikolova, 2013). According to Osbourne (2014) and Wu and Jen (2016), when a tool has been developed using an instrument such as an Exploratory Factor Analysis (EFA) or any similar techniques another EFA should be executed to investigate if the tool shows similar results across the population. An EFA is able to show if, or how, different structures and functions of a measurement tool behave differently with different samples. As the previous study conducted by Bohle Carbonell et al. (2016) identified their three factors using EFA we will conduct an EFA also whether to investigate if the data at hand complies with the research model of this current study sample. Before executing the EFA using SPSS, we assessed the factorability of the data. We started with examining the appropriateness of the data set regarding sample size and parametric test assumptions. Secondly, we examined the scree plot and analyzed the eigenvalues (>1) (Appendix 2). And lastly, components were rotated based on the results.

Kruskall-Wallis test

To answer the second sub-question we used the Kruskal-Wallis test.

Sub-question 1: Is there a relationship between adaptive expertise and attending the Technical Medicine program. Does the level of adaptive expertise from the technical medicine students increase every year they attend university?

H1: There is a positive correlation between adaptive expertise and following a Technical Medicine bachelor program.

This is a nonparametric (distribution-free) test, which is used when the assumptions of the one-way ANOVA are not met because the dependent variables are not normally distributed. Usually, the Kruskal-Wallis test is used to compare three or more (ordinal) variables, which is the case for this hypothesis: knowledge structures, metacognitive capabilities, innovative skills, and cohorts.

If the p-value scores 0.05 or lower there is statistically a significant difference between the outcome of the independent groups. As a result, a Mann-Whitney U test or Dunn for pairwise comparisons should be indicated. When the p-value is greater than 0.05 then the findings are not statistically significant. (Field, 2013).

Spearman's rho test

To be able to answer sub-question 3 we used the Spearman's rho test.

Sub-question 2: Is there a relationship between adaptive expertise and SDL. Are technical medicine students which claim to have SDL skills better scoring on adaptive expertise than their peers? **H2:** There is a positive correlation between adaptive expertise and self-directed learning skills.

Hypothesis two expected a positive correlation between adaptive expertise and self-directed learning skills. To find a correlation we conducted a Spearman's rho. A Spearman's rho measures the strength of association between variables. For this hypothesis, the variables are adaptive expertise (the three following components combined), knowledge structures, metacognitive capabilities, innovative skills, and self-directed learning.

The strength of association between two variables is measured between -1 and +1. However, we can assume that our correlations will not have exact values of -1, +1, or 0. As a result, the values have been categorized to create a value range from nonexistent to very weak. In the literature, the ranges vary slightly, for the purpose of this study we used the following ranges of correlating coefficient and strength of association:

Fig 4. Range of correlation coefficient & Strength of Association

Range of correlation coefficient	**Strength of Association**
Greater than .80	Very Strong
.61 to .80	Moderate to Strong
.41 to .60	Weak to Moderate
.21 to .40	Weak
.00 to .20	Nonexistent to Very Weak

A positive correlation coefficient indicates a positive relationship while a negative correlation coefficient indicates a negative relationship. When the correlation coefficient is exactly zero this means there is no relationship between the variables. However, even if the correlation coefficient is zero, a non-linear relationship may be present (Field, 2013).

Wilcoxon signed-rank test

Answering sub-question 3 we used a Wilcoxon signed-rank test.

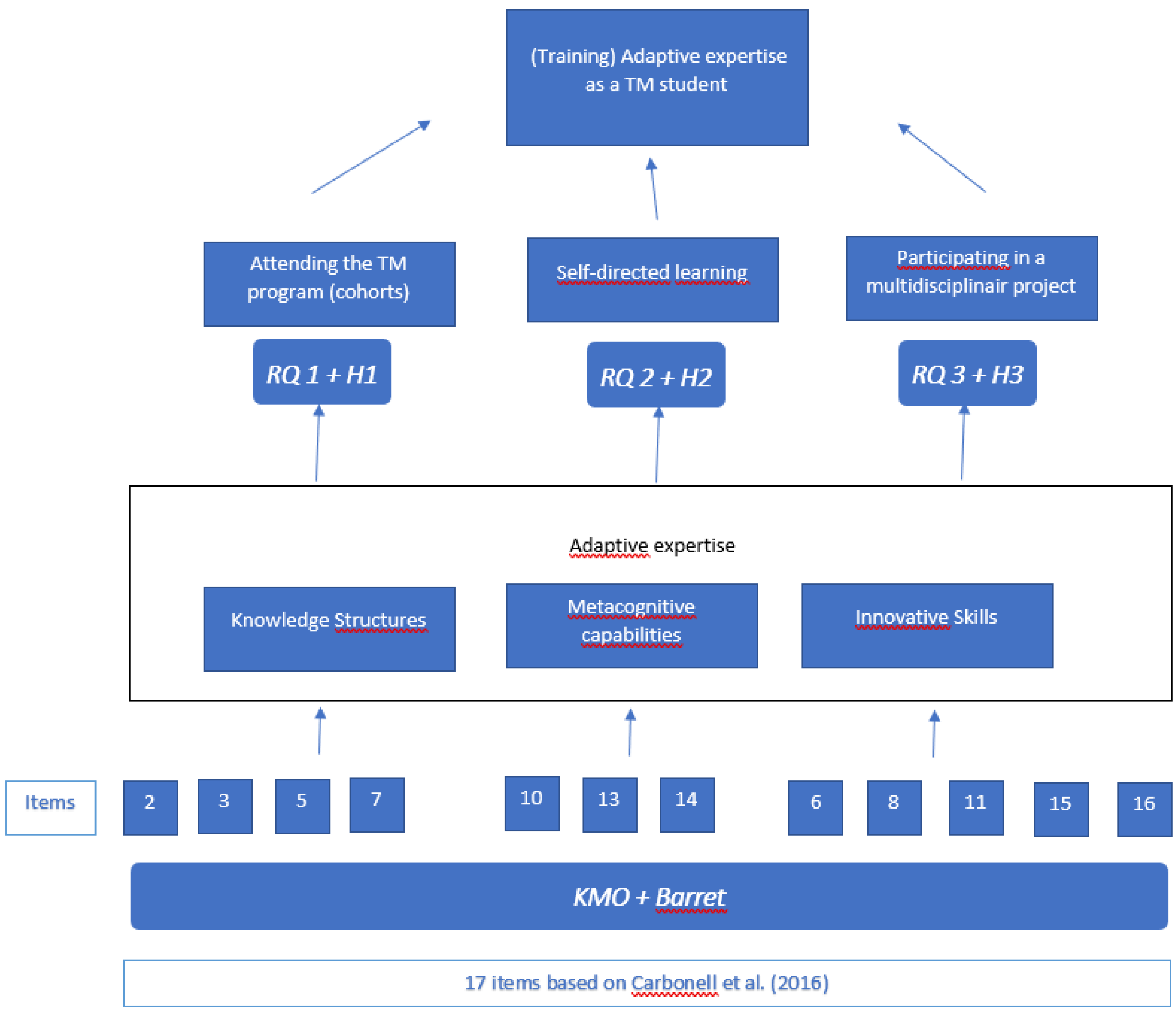
Sub-question 3: Is there a relationship between adaptive expertise and participating in multidisciplinary projects? Are technical medicine students growing their adaptive expertise during their Bachelor's thesis?

H3: There is a positive relationship between adaptive expertise and participating in a multidisciplinary project.

To test if there is a positive relationship between adaptive expertise and participating in a multidisciplinary project we conducted a Wilcoxon signed-rank test. A Wilcoxon signed-rank test is a non-parametric test which means the test does not assume the data comes from a particular distribution, such as a normal distribution. The used data must come from two samples which should be paired or matched. In this case, we have paired data as we look into scores from before the multidisciplinary project and when the students finished the project (Field, 2013). Measuring adaptive expertise as a variable at the start and the end.

Research model

Fig 5. Research Model



Chapter 4

This chapter describes the results and implications of our research. With the help of several comparisons between data groups, we will provide answers to the hypotheses of this study. But first, we start with the reliability and validity of our research instrument

4.1 Results

Table 1 shows results of the Kaiser-Meyer-Olkin of Sampling Adequacy and Barlett’s test of sphericity. This table shows two tests that demonstrate the suitability of the data sample for structure detection. The Kaiser-Meyer-Olkin of Sampling Adequacy is a statistic that displays the proportion of variance in variables, which might be caused by underlying factors (Field, 2013). Values close to 1.0 indicate that a factors analysis has useful data, if the value is below 0.50 it is considered not very useful. Barlett’s test of sphericity tests whether the variables are related and therefore suitable for structure detention. Values under 0.05 of the significance level indicate that factor analysis could be useful with the data (Field, 2013). The test indicates that the result is significant ($P < 0.001$) and that the KMO has a value of 0.661. Therefore, we can assume that the sample size is sufficient for further use.

Looking at table 2 (Appendix 1), which shows the mean and median values of the sample for the 17 items which belong to the three dimensions (appendix 3), we can conclude that the dimension of knowledge structures had the highest mean with a score of 4.2. The other two domains both score 3.6.

Additionally, we checked if the variables were normally distributed. When using a Shapiro-Wilk test, if the sig. value is greater than 0.05, the data is normal. If it is below 0.05, the data significantly deviates from a normal distribution. Therefore, Appendix 4 shows that the indicated variables are not in a normal distribution.

According to Tabachnick, Fidell and Ullman (2007), our sample size (N=114) was acceptable for conducting a factor analysis as they recommend having between five and ten participants per variable. Our initial analysis indicated seven components with an eigenvalue greater than 1, which is the criterion of Kaiser (1960), explaining 18%, 11%, 9,%, 7%, 7%, 6%, and 6% of the variance respectively. However, only one of the seventeen communalities exceeded 0.6, and the average was just below 0.4 (0.391). With a sample size smaller than 250 this showed that the Kaiser criterion was not sufficient (Field, 2009). Although the Kaiser-Guttman rule states that components with eigen values greater than 1 should be retained and are above average we deemed seven as too many factors.

As a result, we looked into reducing the components. We chose three as there were three components to start with and regarded the other four redundant. However, when extracting three components, several loadings scored below 0.4 (Pett, Lackey & Sullivan, 2003) and the variance of the three components was just below 40% (39.14%). According to Steiner (1994), this should be at least 50%. To assure the variance increased we regrouped the questions which resulted in three newly formed components and eliminated 5 questions: Q1_KS, Q4_META, Q9_IS, Q12_IS & Q17_IS. Additionally, we reversed question 15 (Q15_IS) from negative to positive (Q15_ISP). To assist the interpretation of these three components a rotation varimax was conducted which allows correlation between the newly formed components (Tabachnick, Fidell & Ullman, 2007). Lastly, we put the fixed numbers of factors on three and suppressed the small coefficients, <0.35.

The resulting three-component solution explained a total of 49.9% of the variance (Component 1 – 23.4%, Component 2 – 14.8%, & Component 3 – 11.7%), increasing the variance by 10% and rounding up to the general rule of thumb of 50% by Steiner (1994). Table 1 shows the loadings after the execution of the rotation.

Table 1

Rotated component matrix of the three components

Rotated Component Matrix

	Component 1	Component 2	Component 3
Q2_KS	,486		
Q3_KS	,728		
Q5_KS	,748		
Q7_KS	,667		
Q6_IS	,780		
Q8_IS		,521	
Q11_IS		,627	
Q16_IS			,793
Q10_META		,737	
Q13_META			,485
Q14_META			,768
Q15_ISP		,620	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 4 iterations.

The reliability of the three newly formed components was examined using Cronbach's alphas. The value for Cronbach's alpha for component 1 was α = ,74. Component 2 α = ,55 and component 3 α = ,50.

The newly formed components kept their old labels as most of the components consist of questions associated with that topic. Component 1 was labeled ‘Knowledge Structures’, Component 2 ‘Innovative Skills’, and Component 3 ‘Metacognitive Capabilities’.

Sub-question 2: Is there a relationship between adaptive expertise and attending the Technical Medicine program. Does the level of adaptive expertise from the technical medicine students increase every year they attend university?

H2: There is a positive relationship between adaptive expertise and following a Technical Medicine bachelor program.

We conducted the Kruskal-Wallis test to examine the differences between four cohorts when looking at the three components that are associated with adaptive expertise. No significant differences were found among the four cohorts because the p-values are greater than the significant level of 0.05 (Table 3). Consequently, we failed to reject the null hypothesis. There does not seem to be a positive relationship between adaptive expertise and following the Technical Medicine bachelor program.

Table 2

Means and standard deviations combined components of AE and cohorts

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Components_AE	114	3,9149	,31143	3,00	4,67
Cohort	114	11,49	92,899	1	5

Table 3

Results Kruskall-Wallis test of the three components

Test Statistics,[b]

	Knowledge_ structures	Innovative_ skills	Metacogniti ve_Capabilit ies
Kruskal-Wallis H	3,776	,655	,557
df	3	3	3
Asymp. Sig.	,287	,884	,906

a. Kruskal Wallis Test

b. Grouping Variable: Cohort

Table 4

Means and standard deviations of the three components separated

Statistics

		Knowledge_structur es	Innovative_skills	Metacognitive_capa bilities
N	Valid	114	114	114
	Missing	0	0	0
Mean		3,9965	3,7804	3,9649
Std. Deviation		,49203	,46963	,43759

Table 4 shows how spread out data values are around the mean(s). The standard deviation of the components combined is small, indicating they are clustered closely around the mean. Whereas the standard deviation of the cohorts are high, which indicates data are more spread out.

When looking at the individual components, separated from each other, there seems to be some growth among knowledge structures. The cohort of 2019/2020 scores a mean of 53.24 while 2016/2017 scores 61.64 and 2017/2018 even scores 65.16. The component innovative skills shows comparable scores with the cohort of 2019/2020 scoring a mean of 57.73 and the cohort of 2016/2017 a mean of 62.86. Although, 2017/2018 scores the lowest with a mean of 54.57.

The component of Metacognitive Capabilities, on the other hand, shows, decreased competence. The youngest cohort, 2019/2020, scores the highest with a mean of 59.29 while the oldest cohort, 2016/2017, scores the lowest mean with 52.64 (Table 5).

Table 5

Mean scores of the three components for each cohort

Ranks

	Cohort	N	Mean Rank
Knowledge_ structures	2016/2017	11	61,64
	2017/2018	38	65,16
	2018/2019	26	51,46
	2019/2020	39	53,24
	Total	114	
Innovative skills	2016/2017	11	62,86

	2017/2018	38	54,57
	2018/2019	26	59,00
	2019/2020	39	57,73
	Total	114	
Metacognitive_Capabilities	2016/2017	11	52,64
	2017/2018	38	57,30
	2018/2019	26	54,98
	2019/2020	39	59,29
	Total	114	

Sub-question 3: Is there a relationship between adaptive expertise and SDL. Are technical medicine students which claim to have SDL skills better scoring on adaptive expertise than their peers?

H3: There is a positive correlation between adaptive expertise and self-directed learning skills.

Trying to test our hypothesis, we conducted several Spearman's rho tests. First, we combined the three components of adaptive expertise to look for a positive correlation with self-direct learning. Secondly, we determined if the components individually correlated with the self-direct learning component.

Table 6

Means and standard deviations of the three components combined and SDL

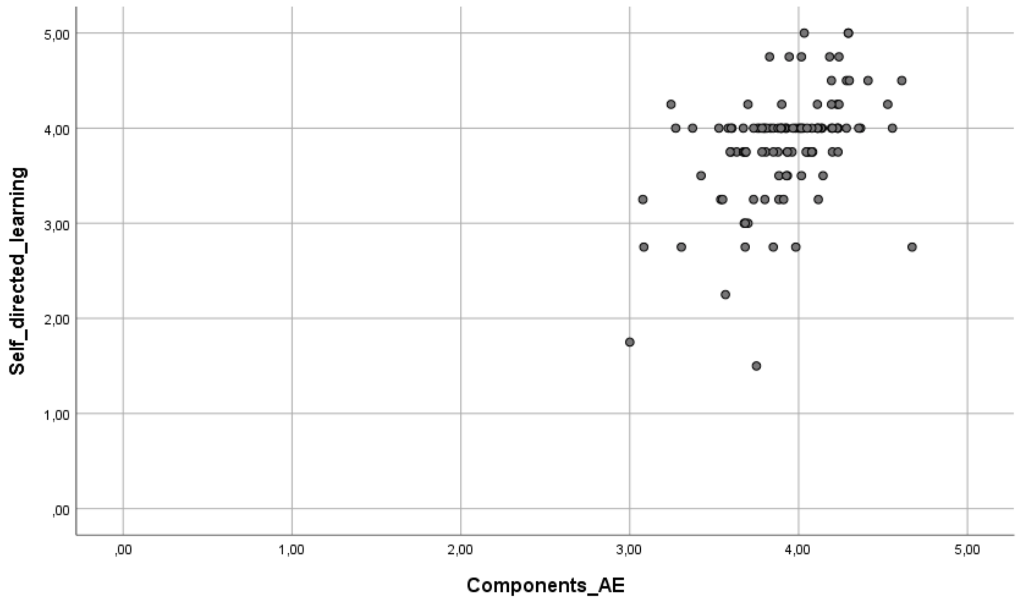
Descriptive Statistics

	Mean	Std. Deviation	N
Self_directed_learning	3,8239	,57827	114
Components_AE	3,9149	,31143	114

Adaptive expertise components & self-directed learning

As we ran a Spearman's correlation to determine the relationship between the components which combined make up adaptive expertise and SDL, we concluded there was a weak to moderate correlation ($r = .456$, $n = 114$, $p < .001$).

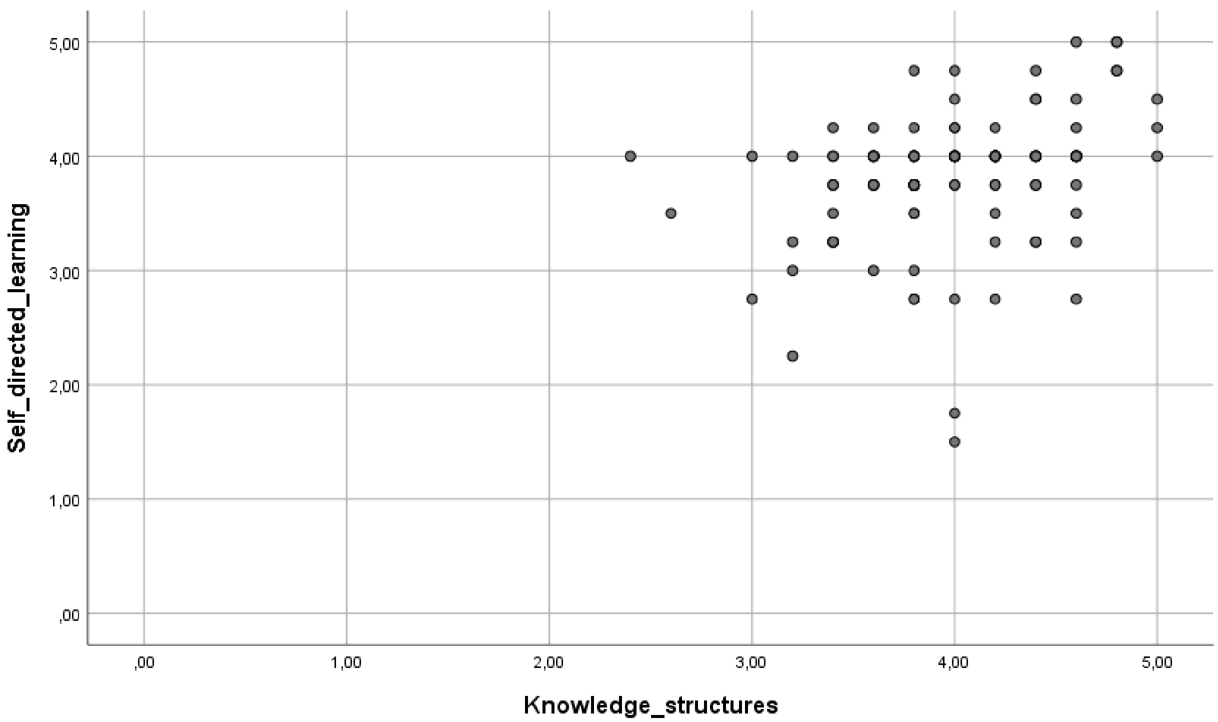
Fig 4. Scatterplot SDL & the combined components



Knowledge structures & self-directed learning

Next up we ran a Spearman's correlation to look at the relationship between the components of knowledge structures and self-directed learning. We concluded there was a weak correlation ($r = .363$, $n = 114$, $p < .001$).

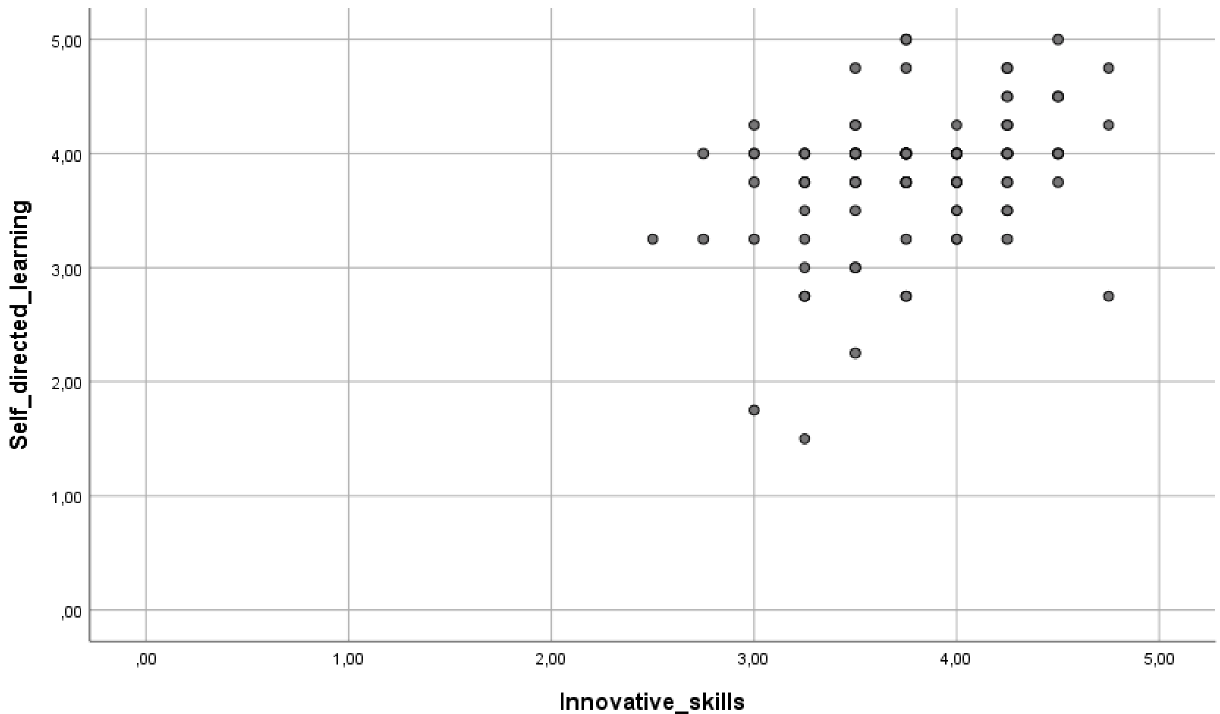
Fig 5. Scatterplot SDL & the component Knowledge Structures



Innovative skills & self-directed learning

The next component that was tested for a relationship with self-directed learning was innovative skills. These components also showed a weak correlation ($r = .351$, $n = 114$, $p < .001$).

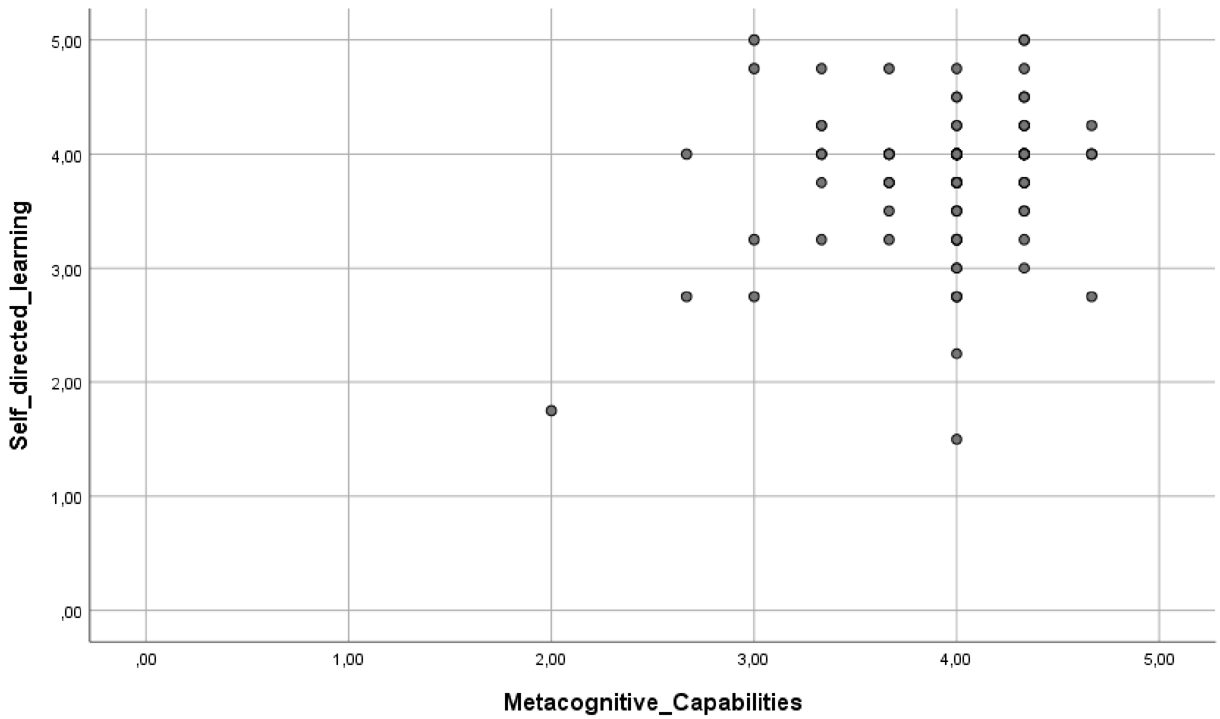
Fig 7. Scatterplot & the component Innovative Skills



Metacognitive capabilities & self-directed learning

And lastly, we ran a Spearman's correlation to look for a positive correlation between self-directed learning and metacognitive capabilities. There does not seem to be a significant correlation between these two components (r= .143, n =114, P >.001).

Fig 8. Scatterplot SDL & the component Metacognitive Capabilities



Sub-question 4: Is there a relationship between adaptive expertise and participating in multidisciplinary projects? Are technical medicine students growing their adaptive expertise during their Bachelor's thesis?

H4: There is a positive relationship between adaptive expertise and participating in a multidisciplinary project.

The Wilcoxon signed-rank test we used showed that participating in a multidisciplinary project for eight weeks in the Technical Medicine program did not elicit a statistically significant relationship. As the test indicated there was no statistically significant increase in adaptive expertise when participating in a multidisciplinary project Z = -4,63, p < ,643.

Table 7

Means and standard deviations of the three components before the project and after

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Components_Before	19	11,3158	,70131	9,62	12,38
Components_After	19	11,1904	,64412	9,88	12,37

Looking at the ranks table we can see that ten students showed a higher level of adaptive expertise before the project than after. However, nine students did score better after the project and 0 students saw no change in their score (Table 8).

Table 8

Means ranks of students before and after the project

Ranks

		N	Mean Rank	Sum of Ranks
Components_After Components_Before	Negative Ranks	10[a]	10,65	106,50
	Positive Ranks	9[b]	9,28	83,50
	Ties	0[c]		
	Total	19		

Chapter 5

5.1 Discussion

The pace at which medical technology and developments are unfolding have never been higher than today. The increasing complexity e.g. augmented/virtual reality, of these developments has changed both organizational needs and strategies. For hospitals, organizational success depends on future doctors. As a result, the subject of individual adaptability has received an ever-increasing amount of attention. Research on routine and adaptive expertise has already produced some insight on this matter. However, hardly any studies have been published to reveal how individual adaptability is applicable and trainable in medical studies. Considering the relevance of this topic, this study aims to contribute to filling up this research gap and provide relevant insights for (future) students and research.

To do so, this study investigated the effect of the Technical Medicine curriculum on the adaptive expertise of its bachelor students. Starting, we set out a questionnaire based on the work of Carbonell et al. (2016). No higher performance was observed when students attended the Technical Medicine study for a longer time than their peers, which was unexpected. However, there seems to be a link between self-directed learning (SDL) and adaptive expertise. Additionally, the multidisciplinary (bachelor) project does not seem to increase the adaptive expertise of the bachelor students. But first, we tested the reliability and validity of our research instrument: a modified questionnaire based on the work of Borne Carbonell et. al. (2016).

While the results of Bohle Carbonell et al. (2016) claimed that their instrument was reliable enough to measure adaptive expertise, we had to adjust the components, eliminate several questions and reverse one of the questions to meet the sufficient reliability score of 0.597. One explanation could be the differences between the samples. Bohle Carbonell et al. (2016) conducted their experiment across two different samples: professionals and graduates. While graduates are novices in their area of expertise given their lack of experience and theoretical domain knowledge, the sample we used is not even close to their level. Moreover, Bohle Carbonell et al. (2016) used a heterogenous sample whereas our sample was homogenous, which fitted our research question.

Another reason for the different outcomes might be the sample size. Bohle Carbonell et al. (2016) already noted in their discussion that their sample size was ‘modest’. Although they used two populations, their sample complete sample consisted of 383 respondents. We only had a sample of 114. According to Bohle Carbonell et al. (2016), an increased sample size bolsters confidence in the instrument’s validity.

We do not have definite answers to explain this stark difference. We need to keep in mind that the study of Bohle Carbonell (2016) did was with the desire for an instrument that is capable of measuring adaptive expertise. This topic is rather new and it is safe to say that future research is needed to find a more valid and reliable measurement instrument. Perhaps another measurement tool could provide additional insight into the adaptive expertise competencies of the Technical Medicine students, delivering other visions for the future.

The first hypothesis suggested that there might be a positive correlation between adaptive expertise and following the Technical Medicine bachelor program. While we expected that there would be a positive relationship no significant difference was found among the four cooperating cohorts. As a result, we failed to reject the null hypothesis. The Technical Medicine bachelor curriculum offers a high variation of learning experiences (Mylopoulos, Kulsagaram & Woods, 2018; Groenier, 2017) and takes a considerable period of time to complete (at least three years). Which in turn grants the students various moments to participate in, and become better in several subjects (Huckman & Staats, 2011; Prahalad & Bettis, 1986). Nonetheless, our results suggest that this is not sufficient.

Another remarkable result shows that the cohort who joined the program earliest (2016/2017) scores the lowest while the first-years (2019/2020) score the highest on metacognitive capabilities. When looking at these results we need to keep in my mind that this is a self-report study in which the students can select a response without further explanation or interference. Students may have exaggerated or misjudged their own competence (Jupp, 2006). Conversely, the older students are more experienced and are possibly more realistic when looking at their metacognitive capabilities, as these are more developed.

Another potentially significant factor regarding the metacognitive capabilities of the younger students is the fact that self-directed learning has been an increasingly popular topic in the Dutch educational scene (VLOR, 2003; 2007). By focusing more on metacognitive capabilities Dutch schools try to prepare their students for the increasing amounts of information which is available, the rapidly changing social and organizational environments, and the individualization of the system (VLOR, 2007).

Overall, none of the three components show a nominal growth. Although, in the long-term, there seems to be an increasing level of adaptive expertise within the cohorts. Curriculum designers should be aware of this unexpected result and look for solutions to fill these gaps in their program. Adaptive expertise, and its components, are an important aspect of the Technical Medicine curriculum structure (Groenier & Miedema, 2017).

Hypothesis two suggested that there should be a positive correlation between adaptive expertise and self-directed learning skills. By adding several questions regarding SDL skills to our questionnaire, we were able to compare the three previously used components with this brand new one and compare the scores. First, we ran a Spearman’s correlation to determine the relationship between the three components combined and we were able to conclude there was a strong, positive correlation. The next step was to look at the components individually in combination with SDL. While knowledge structures and innovative skills showed positive correlations, metacognitive capabilities did not. This is an unexpected result as SDL and metacognitive capabilities are closely linked.

Although our overall results indicate that there is a positive relationship between the two variables when the three components are combined, we need to keep in mind that we used a population with a similar, high level, educational background. There is hardly any variation as the sample consists of university students who can be expected to display greater autonomy and have higher abilities regarding planning, organizing, and analyzing their learning needs, which are examples of metacognitive capabilities (Shin, et al., 2003), in comparison with peers with a lower level of education (Klaser, 2018). As mentioned before, Cornelissen (2012) and Stockdale (2003) concluded that a high level of education and SDL are related. Additionally, there has been no research on which facets of SDL occur differently among these different groups.

Another factor that we need to take into account is the institution of the population. The Technical Medicine curriculum aims to develop SDL skills and hopes to enhance the adaptive expertise of their students. Whereas in other institutions there could be a population of similarly educated people, their results could be completely different. Institutions that depend on people with Beta studies will probably score lower on SDL skills than their Alpha study peers. In general, technical studies are less focused on factors that influence SDL, such as career guidance and the development of career identities (Nieuwenhuis, 2006).

When looking at our research setup, the interpretation of our SDL-based questions may have influenced the results. These questions were created based on SDL literature (Ellinger, 2005), and although they were tested and validated, may have created some questions or misunderstandings with students when they filled out the questionnaires. This, in turn, may have delivered some wrong insights. Additionally, similarly to the questions about metacognitive capabilities, there could be instances of exaggerating and underestimation. This is evident when working with self-reported measurement tools.

Hypothesis three suggested that there would be a positive relationship between adaptive expertise and participating in a multidisciplinary project. After conducting a Wilcoxon Signed-Ranks test, we concluded that there was no statistically significant increase in adaptive expertise. The students who participated did not show meaningful growth. But looking at the sample we can identify several issues. Although over 100 students participated at the start, only 19 students managed to fill in our questionnaire twice. Thus, it is questionable whether this can be considered sufficient to answer our question. Additionally, we had a ratio of 85% women and 15% men.

Looking at the literature, a multidisciplinary project could be a wonderful asset to increase the adaptive expertise of the students as it issues them to participate in a range of different disciplines of their expertise (Choi & Pak, 2006). Several authors argue that to train adaptive expertise, students should have a variety of learning experiences. Decreasing similarities between previous and current learning experiences is beneficial for factors influencing adaptive expertise such as conceptual thinking and innovative skills (Dries, Vantilborgh, & Pepermans, 2012; Karaevli & Hall, 2006; Dawis & Lofquist, 1984; Griffin & Hesketh, 2003). An alternative explanation for this outcome could be the limited length of the project. To see some significant growth, the project may need to be extended over a longer period of time. Another possible issue could be the division of roles of the students at hand. If they chose to all do just one part of the project, which fits the individual best, they will not experience the diversified learning experiences they otherwise might have benefitted from.

5.2 Strengths and limitations

Our study had several strengths. Using a quantitative way to measure data, a questionnaire, we were able to reach a respectable portion of the students during the peak of the COVID pandemic. This resulted in a representative sample with a homogeneous population. To do so, we used a validated measurement tool and adjusted it to fit our population and (sub)research question, adding and extracting several questions and revalidating the questionnaire using the KMO and Barlett’s Test of Sphericity plus the Exploratory Factor Analysis. Also, we took the opportunity to look into the link between adaptive expertise and self-directed learning. This provided some interesting insights for future research and the Technical Medicine program.

While we can conclude that the present study revealed important information regarding adaptive expertise and self-directed learning, there are several limitations to this study. When looking at the results, our sample was certainly representative. However, whether our sample size was adequate is debatable. Especially when we look at sub-question four. Therefore, further study with a bigger sample is highly recommended. Also, it should be noted that our research only applied subjective measurement methods resulting in a self-reported study that promotes inflexibility, over-and underestimation, and a lack of depth. Therefore, caution is to be taken when interpreting the present results.

Another limitation is the added question that involved SDL to the existing questionnaire of Bohle Carbonell et al. (2016). This cannot be considered a strong measurement of SDL and therefore should be expanded to be able to make stronger generalizations from the present results. Additionally, by using the questionnaire of Bohle Carbonell et al. (2016) we always considered the subject from the same perspective. Another tool could give other insights.

5.3 Future research and recommendations

For future research, it would be interesting to replicate this study for several reasons. As mentioned before, the sample size of this study was rather small. It would be interesting to see how a bigger sample size would affect the results. Also, to be able to counter the limitations of a self-reported questionnaire, a more direct measure of adaptive expertise should be designed and implemented such as interviews or rubrics (Pierrakos, Anderson & Welch, 2016). While interviews can provide detailed information about the participants, they are also very time-consuming when working with a big sample and could be influenced by the researchers. A standardized rubric with pre-and post-test responses could be a direct method to measure adaptive expertise when working with a relatively big sample. Unfortunately, at this moment there is no single coherent framework which describes the components of adaptive expertise. Further research on this framework together with the components could enhance the chance of a validated adaptive expertise measurement tool. This tool could decrease the notable gap in the development and validation of adaptive expertise measurement tools (Kua, Lim, Teo & Edwards, 2020).

Secondly, the current study only uses one subjective measurement tool and it would be interesting to use triangulation by combining this method with (an) objective measurement tool(s). Triangulation is used to increase the credibility and validity of a study's findings. By combining various theories and methods triangulation can help to discover fundamental biases which arise from a single method. This could help prevent biases such as perception bias (Noble & Heale, 2019).

Thirdly, when looking at the multidisciplinary project, it would be interesting to investigate teams with pre-and post-measurement instead of individual students, looking at team adaptive expertise. According to Kozlowksi (1998), adaptive expertise can be applied to teams. Adaptivity in teams occurs when assignments and demands are uncertain and the workload increases, which is natural when working in multidisciplinary projects (Entin & Serfaty, 1999). Team adaptive expertise includes metacognitive and self-regulatory skills for both the development of individual cognitive and team processes. Examples are monitoring yourself and others and the ability to change and support others with their roles, developing a shared and mental model, and coordination (Paletz, et al., 2013).

Also, studying diversified learning tasks within the existing curriculum of the technical medicine program could reveal important information for improving adaptive expertise among students. According to Mylopoulos, Kulasegram and Woods (2018) diversified learning tasks are determinants that could predict adaptive expertise. It has been theorized that when one is experiencing diversified learning, this can stimulate the development of extracting general principles, conceptualizing and interpreting environments, and the ability to transfer previous learning to the current topic (Dries, Vantilborgh, & Pepermans, 2012; Karaevli & Hall, 2006). Additionally, several studies hypothesize that diversified learning experiences are necessary, as these experiences support the likelihood of adaption and increase the probability of individual behavioral adjustments and the development of innovative skills. (Dawis & Lofquist, 1984; Griffin & Hesketh, 2003).

For now, we conclude that the bachelor assignment does not have the potential to increase the adaptive expertise of the students. But, throughout the whole curriculum, there are several learning tasks and for now, we are unable to tell which influences the students significantly, or barely. Figuring out which are influential, and which are not, can be beneficial for developing a new technical medicine curriculum. Additionally, other areas of expertise could profit as well.

Lastly, while none of the three components show a nominal growth in combination with SDL, there seems to be a long-term effect. It would be interesting to find out why. Does the Technical Medicine program attract a certain type of student, who already has a certain level of adaptive expertise and SDL? How trainable is adaptive expertise in this phase of life? Or is real work experience necessary to be able to grow? Only future research can tell.

Chapter 6

6.1 References

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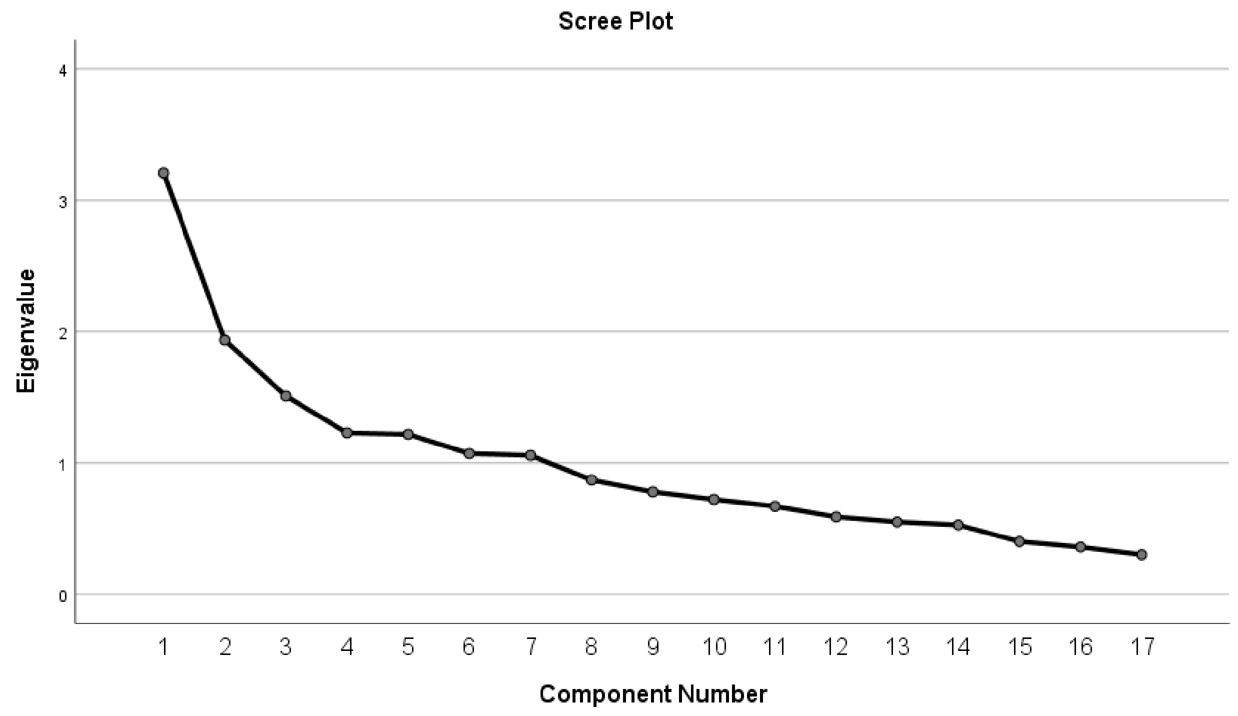
7. Appendix

Appendix 1 :

Statistics

		Q1_KS	Q2_KS	Q3_KS	Q5_KS	Q7_KS	Q12_FLEX	Q15_FLEX	Q6_FLEX	Q8_FLEX	Q9_FLEX	Q11_FLEX	Q16_FLEX	Q17_FLEX	Q4_META	Q10_META	Q13_META	Q14_META
N	Valid	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		4,74	4,42	3,36	3,92	4,55	3,59	2,01	3,74	4,09	3,81	3,81	3,86	3,51	2,95	3,23	4,00	4,03
Median		5,00	4,00	3,00	4,00	5,00	4,00	2,00	4,00	4,00	4,00	4,00	4,00	4,00	3,00	3,00	4,00	4,00
Std. Deviation		,441	,621	,786	,774	,581	,736	,656	,727	,571	,826	,674	,544	,779	,887	,930	,704	,591

Appendix 2: screeplot & component matrix



Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
Q6_FLEX	,741	-,355					
Q3_KS	,729						
Q5_KS	,661				-,398		
Q2_KS	,529				,357		
Q7_KS	,526		,344	-,349			
Q11_FLEX	,505		-,431	-,306			
Q17_FLEX	,484					,331	-,301
Q16_FLEX		,646	,308				
Q14_META		,514	,453	-,377			
Q13_META		,504		,503			
Q15_FLEX		-,439	,338		,419		
Q10_META		,459	-,562				
Q12_FLEX		,452		,537			,369
Q9_FLEX	,422				,519		-,349

Q8_FLEX			-,367			,597	
Q4_META			,474		-,432	,554	
Q1_KS	,323				,303		,624

Extraction Method: Principal Component Analysis.

a. 7 components extracted.

Appendix 3

Adaptieve expertise Technische Geneeskunde

INFORMATIE EN TOESTEMMING

U wordt uitgenodigd om mee te doen aan een onderzoek naar Adaptieve Expertise binnen de opleiding Technische Geneeskunde. Dit onderzoek wordt uitgevoerd door Jan Menting, Master student Educational Science and Technology aan de Universiteit Twente.

Wat wordt er van u verwacht? Meedoen aan het onderzoek houdt in dat u een online vragenlijst gaat invullen. De vragen hebben betrekking op Adaptieve Expertise binnen de opleiding Technische Geneeskunde. Het invullen van de vragenlijst kost ongeveer 10 minuten.

Vrijwilligheid U doet vrijwillig mee aan dit onderzoek. Daarom kunt u op elk moment tijdens het onderzoek uw deelname stopzetten en uw toestemming intrekken. U hoeft niet aan te geven waarom u stopt.

Wat gebeurt er met mijn gegevens? De onderzoeksgegevens die we in dit onderzoek verzamelen, gebruiken we voor kwaliteitsverbetering van de opleiding en wetenschappelijke publicaties.. Als we gegevens met andere delen, zullen deze niet herleidbaar tot uw antwoorden zijn.

We bewaren alle onderzoeksgegevens op beveiligde wijze volgens de richtlijnen van de Universiteit Twente. Alleen de hoofdonderzoeker, Jan Menting, heeft toegang tot de niet geanonimiseerde data.

Ethische toetsing, klachten en vragen Dit onderzoek is goedgekeurd door de Ethische Toetsingscommissie Behavioural, Management and Social sciences (BMS) van de Universiteit Twente. Heeft u klachten of vragen over de verwerking van gegevens in dit onderzoek kunt u contact opnemen met: J.G.T.Menting@student.utwente.nl

Bedankt voor uw medewerking!

Toestemming:

○ Ik geef toestemming

○ Ik geef geen toestemming

Beste TG student,

Bedankt voor je deelname.

We beginnen met wat algemene vragen met daaropvolgend eenentwintig vragen over adaptieve expertise.

Mocht je de vragenlijst tussentijds afsluiten kan je daarna verder waar je gebleven was.

Nogmaals bedankt,

Jan Menting - Master student Educational Science and Technology.

Q1 Begonnen met studeren in cohort

- ☐ 2015/2016
- ☐ 2016/2017
- ☐ 2017/2018
- ☐ 2018/2019
- ☐ 2019/2020
- ☐ 2020/2021

Q2 Gender

- ☐ Man
- ☐ Vrouw
- ☐ Anders

End of Block: Informatie studenten

Start of Block: Adaptieve expertise

	Zeer mee oneens	oneens	Neutraal	eens	Zeer mee eens
1. Ik ben mezelf ervan bewust dat de bestaande kennis in Technische Geneeskunde zich blijft doorontwikkelen	○	○	○	○	○
2. Gedurende mijn opleiding heb ik over het algemeen meer kennis vergaard over het vakgebied Technische Geneeskunde	○	○	○	○	○
3. Ik hou mijzelf bezig met de nieuwste ontwikkelingen binnen Technische Geneeskunde	○	○	○	○	○
4. Ik benader Technische Geneeskunde net zoals eerdere projecten of scholing in het verleden	○	○	○	○	○
5. Ik heb laten zien dat ik mijzelf wil verdiepen in nieuwe aspecten gerelateerd aan Technische Geneeskunde	○	○	○	○	○
6. Ik focus mezelf op nieuwe uitdagingen binnen Technische Geneeskunde	○	○	○	○	○

7. Ik ben mezelf ervan bewust dat ik door moet gaan met leren om een expert te blijven in het gebied van Technische Geneeskunde	○	○	○	○	○

Page Break

	Zeer mee oneens	oneens	Neutraal	eens	Zeer mee eens
8. Wat ik in het verleden heb geleerd heb ik kunnen toepassen in deze opleiding en daardoor nieuwe kennis kunnen vergaren	○	○	○	○	○
9. Als ik ergens niet uitkom of een idee over heb vraag ik om feedback	○	○	○	○	○
10. Als ik tijdens de opleiding geconfronteerd werd met iets onbekends dan had dit geen invloed op mijn presteren	○	○	○	○	○
11. Tijdens de opleiding kan ik mijn kennis flexibel toepassen binnen verschillende disciplines	○	○	○	○	○
12. Als ik ergens tegenaan loop tijdens de opleiding kan ik de reden hiervoor vinden	○	○	○	○	○
13. Ik ben in staat om mijn werkgewoontes toe te passen tijdens deze opleiding (manieren van leren etc.)	○	○	○	○	○

14. Ik ben in staat om te zien wanneer mijn kennis ondermaats is bij het uitvoeren van opdrachten en of behandelingen	○	○	○	○	○

Page Break

	Zeer mee oneens	oneens	Neutraal	eens	Zeer mee eens
15. Wanneer ik werd geconfronteerd met obstakels of moeilijke situaties gaf ik op	◯	◯	◯	◯	◯
16. Ik ben in staat om te zien wanneer mijn vaardigheden ondermaats zijn bij het uitvoeren van opdrachten en of behandelingen	◯	◯	◯	◯	◯
17. Ik heb mijn opgedane kennis van de opleiding met enige mate van succes toegepast in onbekende situaties gerelateerd aan Technische Geneeskunde	◯	◯	◯	◯	◯
18. Ik ben in staat om zelfstandig vast te stellen wat ik te leren heb	◯	◯	◯	◯	◯
19.Ik ben in staat om zelfstandig betekenisvolle leerdoelen te formuleren	◯	◯	◯	◯	◯
20. Ik ben in staat om zelfstandig aan de slag te gaan met mijn leerdoelen	◯	◯	◯	◯	◯

21. Ik ben in staat om zelfstandig mijn leerdoelen te behalen	○	○	○	○	○

End of Block: Adaptieve expertise
