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Doctoral thesis

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Norwegian University of Science and Technology
Thesis for the Degree of Philosophiae Doctor
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Preface

This thesis is the culmination of years of supervision, guidance, and support from various people I would like to thank wholeheartedly. Most of all I would like to thank my mentor Gabrielle Hansen, and supervisors Reidar Lyng and Frode Rønning. I have been very lucky to have such a skilled group of people support me and help me develop as a scientist. Furthermore, special thanks to Guri Sivertsen Korpås for all the interesting conversations, and I hope that we in the future can collaborate uninterrupted by corona or other external challenges. To all peers and colleagues at NTNU and across the world, thank you all for guidance, support, the belief in me, and creating good memories.

Furthermore, I would like to give a special thanks to everybody who participated in the study and helped developing a clearer picture on how it is to transition to Active Learning Spaces. Thanks to the students who answered and elaborated on their experience in the survey, and especially so to the students who participated in the focus-group interviews and shared many happy but also difficult moments from their classes. Special thanks to the teachers who took time to participate in this study, transitioned to the Active Learning Spaces, and allowed me to interview and survey their students. It was fun and interesting to be a part of the conversations with you, and I hope that your elaboration on how the Active Learning Spaces impacted you will be used to improve teaching and learning for future generations. I wish you the best in your future teaching endeavors.

I am particularly grateful to friends and family for your support and love you have provided throughout these challenging years. There have been many nice weekend trips, dinners, swims, boardgame nights, ski-trips, and more. Thanks to Stian and Dmitri for being great neighbors. Thanks to Vegard for being a great office mate and entertaining and discussing many and diverse topics. Finally, Lara, many pages could be spent declaring how great you have been and how deep my love for you is. Without your love and support I would never have completed my PhD. Thank you. I am very much looking forward to the next chapters of adventures together.

Summary

Active Learning Spaces (ALSs) are spaces designed to facilitate for Active Learning (AL), often improving the benefits of such teaching methods. The impact of AL has been extensively researched, and evidence suggest that AL generally improves students' learning outcomes. As AL has been increasingly addressed, so have spaces designed to facilitate for AL been designed and discussed. These spaces, here referred to as ALSs, have generally been found to enhance the positive outcomes of AL. A topic that has been less researched is what challenges teachers and students experience when they are working in ALSs. Even less researched is how such challenges are experienced by teachers transitioning into ALSs and students who are mostly new to ALSs. While ALS use is often beneficial, it is not without challenges to both teachers and students, and it is highly desirable to better understand these challenges, as well as the benefits of using these spaces to increase the knowledge of how to use ALSs beneficially.

The aim of this thesis is not to measure the student learning outcome of AL and ALSs. Instead, the goal is to understand better the challenges and factors that have been perceived by teachers and students as important in their process of using ALSs.

The thesis takes a closer look at the use of ALSs in mathematics and statistics courses through the perceptions of teachers and students at the Norwegian University of Science and Technology (NTNU). In order to investigate perceived challenges of transitioning to ALSs, a team of four teachers was formed by the researcher. All four were new to using ALSs, and their perceptions of their adaptation to the ALSs highlighted how they experienced this transition process. They were already interested in teaching with AL methods but had yet to transition into ALSs. In addition, the interactions with the researcher provided the teachers with support to overcome basic challenges in the process, and a better teaching experience. Such interactions and support also lay the ground for more profound reflections concerning ALSs, albeit at the price of introducing some added subjectivity by the researcher in a research method that already is characterized by some subjectivity.

The data from the teachers consist of classroom observations, post-observation conversations with the teachers after observing some of their classes, group reflection conversations with the team of teachers, and individual semi-structured interviews. The data from the students consist of classroom observations, surveys, and semi-structured focus group interviews.

A consistent theme in the results is how the teachers express that it is essential, yet challenging, to have students engage in the active elements. Further, the students often chose

not to participate in the classes due to the discomfort that they experienced. Several strategies were suggested by the teachers to reduce discomfort and increase engagement, such as building good student relations and developing good teaching strategies. It is also reflected that in mathematics and statistics, conceptual and contextual tasks are experienced as positive for creating engagement and discussions between students.

In summary, this thesis contributes to the growing general knowledge of ALSs, specifically addressing teachers' and students' experiences of transitioning to these spaces. Challenges related to AL use in the ALSs are also addressed. A better understanding of ALSs can highlight potential problematic areas of using these spaces and lay the ground for enhancing future use of such spaces.

Abbreviations

AL – Active Learning
ALS(s) – Active Learning Space(s)

EVT – Expectancy-Value Theory
AAT – Approach-Avoidance Theory
IET – Interaction Equivalency Theorem
IAR – Interactive Action Research
SRS – Student Response System

NTNU – Norwegian University of Science and Technology
STEM – Science, Technology, Engineering, and Mathematics

List of Papers

I. **Aga, K.** (2023a). Challenges and motivation for teachers transitioning to active learning spaces. *European Journal of Engineering Education*, *48*(4), 724-746. https://doi.org/10.1080/03043797.2023.2193552

II. **Aga, K.** (2023b). Comfort in Active Learning Spaces – Students' perceptions and preferences. [Manuscript submitted for publication]. Department of Mathematical Sciences, Norwegian University of Science and Technology.

III. **Aga, K.** (2023c). Mathematics in Active Learning Spaces. [Manuscript submitted for publication]. Department of Mathematical Sciences, Norwegian University of Science and Technology.

Contents

1 Introduction

A fundamental purpose of higher education is to ensure that students acquire knowledge and skills. Substantial evidence support that when Active Learning (AL) is performed in Active Learning Spaces (ALSs), student learning outcomes, such as knowledge retention, engagement, and exam results increase. Nevertheless, implementing AL or ALSs does not guarantee improved student learning outcomes. This thesis will explore factors and conditions inherently linked to ALSs' efficacy.

This thesis' primary goal of establishing fundamental factors and conditions that impact the efficacy of ALSs is explored through three papers. The first paper examines four teachers' perceptions of transitioning to teaching in the ALSs, the second examines the perceptions on ALSs by the students of the same teachers, and the third examines reflections by the teachers and students on how the course subject being mathematics or statistics had any specific relevance to the use and value of ALSs. Indeed, all three papers are primarily concerned with understanding how students and teachers interact in ALSs. It is also of interest to discuss how such understanding can improve educational quality through measures such as facilitating for professional development that supports teachers' transitioning to ALSs. Enhancing the comprehension of students' perceptions of ALSs can support the implementation of existing strategies to engage students in the ALSs. Furthermore, a better understanding of the value of ALSs may also support the development of learning spaces, and the educational staff's decision-making concerning teaching-learning designs in ALSs.

However, before presenting the results from this work, the framework and theories used to understand the research material will be presented. This includes motivational theories such as Expectancy-Value Theory and Approach-Avoidance Theory. A definition of ALSs will be given and the motivation for looking closer at ALSs will be discussed shortly. The motivational theories were employed to illustrate how teachers and students worked in the ALSs. Other elements, such as task types and professional development, are briefly discussed. Some elements, such as institutional change plans and how to influence government policies to help the institutions to better support teachers' focus on best practice use of AL and ALSs, have mainly been left for later discussions. To close, while professional development and institutional change are mentioned regarding how teachers transition to ALSs, discussing institutional culture in depth is beyond the scope of this thesis.

1.1 The Context of the Study

The importance of understanding, using, and developing appropriate ALSs is increasingly recognized on a national and institutional level. On a national level, a government report has declared that teaching should be informed by research on teaching and learning (Meld. St. 16, 2017). Moreover, the same report recognizes the importance that the physical design of buildings plays on students' enjoyment and learning and that it is desirable to encourage an outlook on physical spaces as a tool to support the institution's goals (Meld. St. 16, 2017).

Reflecting the national commitment, the university where this research was conducted, NTNU, has committed to developing more ALSs in a campus development project that involves the construction of several new buildings (NTNU, 2019b, 2023b). In addition, many ALSs have already been developed in the existing buildings (NTNU, 2023a, 2023c).

This research project was initiated and partially funded by TettPÅ (NTNU, n.d.-c). TettPÅ was a project at NTNU that initially focused on the development of innovative response technologies for use in teaching and assessment, development of good feedback situations, interactive teaching methods, formative assessment practices, and effective collaborative learning (NTNU, n.d.-c). However, with the focus on the campus development project it was decided that there was also a need for understanding the use and challenges related to ALSs.

There is a growing awareness that in the past there has been a lack of strategy and awareness of the different roles that different spaces can play in education. Therefore, NTNU has recognized a need for more research on learning spaces, including ALSs, to evaluate the impact on teaching and learning quality, to inform future strategy and use, to better understand the effects of spaces similar to ALSs, to make better and more informed decisions, mitigating suboptimal use and development of spaces, and to guide the continual development and upgrading of learning spaces (NTNU, 2019a, 2019b, 2023c).

Therefore, this research is a timely contribution. There is a need to explore the perceptions of teachers and students in ALSs in the cultural and institutional setting at NTNU. In addition, NTNU educates many STEM[1] students and others who need proficiency in mathematics and statistics, and a better understanding of how to facilitate improved education in these subjects that many students find difficult, is core to improving the overall educational quality at NTNU.

[1] Science, Technology, Engineering and Mathematics

A recent project, called Technology Studies for the Future (FTS) established ten principles for improving STEM education at NTNU (Fremtidens teknologistudier, 2022; NTNU, 2023c; Øien & Bodsberg, 2021). These principles have been approved by the rector to act as guidelines for developing STEM education at NTNU (Fremtidens teknologistudier, 2022, p. 11). Three of the FTS principles are strongly related to the topics of this thesis: contextual learning, student-active learning, and pedagogical competence development for the teaching staff. To truly transform STEM education, it is necessary to go beyond developing the subject matter to also developing the educational design. Central to this ambition is to understand the challenges the teachers and students face and provide the appropriate support to overcome these challenges. Such support includes developing the teaching staff's pedagogical competencies and aiding them in developing the skills they need to engage their students and to teach successfully in ALSs.

Beyond the national scope, quality education is a key goal in the United Nations sustainability goals (UN General Assembly, 2015). This goal does not explicitly mention ALSs but supports equitable education, life-long learning, and education that facilitates and provide effective learning environments for all.

1.2 Relation Between this Thesis, AL, and ALSs

The focus of this thesis is how teachers and students perceive the use of ALSs and the transition to ALSs. It does not address the efficacy of AL strategies or how the design of ALSs influences the students' learning outcomes. A short discussion on the definition of Active Learning (AL) is presented in Section 1.3, followed by a discussion in Section 1.4 about what can meaningfully be understood to be an Active Learning Space (ALS).

In order to situate the research, it is desirable with some background on ALSs, and to situate the understanding of ALSs, it is beneficial to first discuss AL. Indeed, over the past decades the increased awareness of AL has led to reflections on the spaces where AL teaching strategies are performed (Finkelstein et al., 2016). Such awareness has led many higher education institutions to invest in learning spaces that facilitate students to be active and engaged during the learning sessions to enhance the benefits of AL, i.e., ALSs (Oblinger, 2006). Evidence suggest that when AL and ALSs are used together, students' learning outcomes are improved (Baepler et al., 2016; Brooks, 2011; Brooks & Solheim, 2014; Fraser et al., 2014; Taylor, 2009). By contrast, using ALSs for traditional lecturing may be perceived worse than using a conventional lecture hall (Aga, 2023a). The core purpose of this thesis is to

examine perceptions related to the use of ALSs. However, a core part of the ALS experience was that AL was used as a teaching strategy in these spaces. Therefore, the terms are frequently used concurrently.

1.3 Active Learning

As discussed in the papers I, II, and III there are many forms of AL, including problem-based learning, flipped classroom, and peer instruction (Barell, 2006; Mazur, 1997). The outlook on AL in this thesis is primarily informed by Bonwell and Eison (1991) and Prince (2004). Bonwell and Eison (1991, p. 19) first stated that active learning is "anything that involves students in doing things and thinking about the things they are doing." Prince (2004, p. 223) later added: "Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing." Essential to Prince's statement is that his definition includes that AL is an instructional method and that the learning activities must be meaningful. However, at the core of AL is that students are doing things and thinking about the things they are doing. While both definitions above could be understood to include homework, AL is in practice understood to be limited to activities done during class.

Bonwell and Eison's and Prince's views on AL are often interpreted not to include traditional lecturing under the umbrella term AL. Traditional lecturing can, however, be interpreted to include AL if during the traditional lectures students are actively encouraged to listen and think about what is being presented. While evidence suggest that most students' learning would be better supported by more active approaches (Freeman et al., 2014), it may also be that for some students, their learning is well supported by the traditional lecture, especially if this environment is conducive to them being cognitively active. Yet, the traditional lecture is frequently contrasted with AL, as for example in Freeman et al. (2014), where student learning outcomes of traditional lectures were compared against the student learning outcomes from AL. By contrasting traditional lecturing with AL, one may lose some nuances. There may be elements in a lecture format that supports learning well. Yet, this contrast also makes it possible to compare AL with lecturing. However, it is important to remember that the evidence for AL, is not evidence against having lecturing elements. Indeed, many who use AL incorporate this into their lecturing routine. Such use of AL is further examined as the teachers present their view on teaching strategy in Paper I.

AL has gained popularity as there is an increasing amount of evidence that this teaching method outperforms conventional lecturing (Crouch & Mazur, 2001; Deslauriers et al., 2011; Deslauriers & Wieman, 2011; Fraser et al., 2014; Freeman et al., 2014; Hake, 1998; Michael, 2006; Springer et al., 1999). One of the benefits of AL is that it can positively impact students' motivation and attitudes toward learning (Cohen et al., 2019). However, just because AL can benefit student learning outcomes does not mean that all ways of implementing AL are beneficial. Discussing how to implement AL best is important and gaining traction (Bernstein, 2018; Johnson et al., 2021). Some challenges to implementing AL that may impede the benefit of this teaching strategy are students resisting the new teaching pedagogy or poor collaboration between students (Deslauriers et al., 2019). Also, research on how active learning is influenced by group work, group composition, and class composition is evolving (Aguillon et al., 2020; Moreland et al., 1996). For example, the size of groups appears to have different impacts depending on the gender ratio of the students. For instance, groups that have a higher female percentage of group members increase both their peer evaluation and the course performance scores for both genders in the group (Sullivan et al., 2018). Such results, incidentally, illustrate the importance of retaining women in STEM and that AL and group work can have varying outcomes based on gender and group composition. By contrast, other results showed that women participate and benefit less from AL (Aguillon et al., 2020). Thus, while it is desirable to both implement AL and retain women in STEM, it is important to do it so that participation is equitable between genders. There is even evidence that women perform relatively better than men in smaller classes, which adds an equity dimension to reflections on class size (Ballen et al., 2018).

Research into AL methods in Norway is growing, with various studies shedding light on its dynamics (Fredriksen, 2021; Fredriksen & Hadjerrouit, 2020; Rensaa & Fredriksen, 2022). It appears to also be true in the context of Norwegian education that promoting active participation enhances the quality of the teaching sessions (Fredriksen, 2021). One challenge of AL is that it may make students feel obligated to engage in tasks, and when students are unprepared, this can be a difficult experience for them (Fredriksen, 2021).

Few studies, however, have thoroughly examined the challenges teachers face when making use of AL and ALSs in mathematics or statistics classes, the students' perceptions related to AL and ALSs, or what specific challenges there may be in using ALSs when teaching mathematics or statistics.

Further aspects of interest to investigate, beyond the scope of this thesis, are how flipped classroom, problem-based learning, and other AL strategies compare. How should professional

development be designed to help teachers effectively use strategies to overcome student resistance and engage their students with their learning activities consistently and effectively?

1.4 Active Learning Spaces

There are many names for the various types of learning spaces designed and built at higher education institutions to facilitate students working together and participating actively in their classes. These spaces are often referred to as Active Learning Spaces (ALSs); other names include "Active Learning Classroom," "Next Generation Learning Space," "TEAL," and "SCALE-UP" (Baepler et al., 2016; Fraser et al., 2014). In this thesis, all such spaces will simply be referred to as ALSs. ALSs will therefore be understood as spaces that are purposefully designed to foster active, collaborative, and student-centered learning. These spaces often incorporate flexible layouts and advanced technology to support varied teaching strategies and learning activities, enabling students to participate directly and interactively in their learning process.

Research indicates that AL performed in ALSs can enhance students' learning outcomes (Baepler et al., 2016; Brooks, 2011; Brooks & Solheim, 2014; Fraser et al., 2014; Taylor, 2009). The benefits of ALSs are primarily attributed to their design, which promotes student interaction (Brooks, 2011). The design of the ALSs has been argued to alter both teachers' and students' expectations on what type of teaching and learning should occur in the space, promoting mindsets that support the use of AL and work to create a social climate that may improve student learning outcomes (Walker & Baepler, 2018)

Evidence also suggest that teachers with beliefs favoring AL succeed better in ALSs than those without (Lasry et al., 2014). However, first-time users of ALSs have frequently been observed not to change their teaching practices, i.e., teachers who lectured continued to do so (Carr & Fraser, 2014). Thus, if one combines the insights from Lasry et al. (2014) and Carr and Fraser (2014) and assumes that teachers' beliefs in AL are related to their actual teaching practice, then a part of ALSs' success related to teachers' beliefs and teaching strategies is in part set before the teachers enter the ALSs. Nevertheless, teachers who employ AL in ALSs found incentives to allow for more flipped classroom teaching (Van Horne et al., 2014). Such change in practices does not necessarily indicate that ALSs changed teachers' beliefs, but rather that teachers already in favor of using AL were encouraged to further develop AL in ALSs. This raises the question to what degree technology in the ALSs may influence the teachers' and students' activities, but also what other activities may benefit from the use of ALSs.

1.4.1 Challenges when Adopting and Adapting ALSs

Despite the desire for more evidence-based teaching practices (Handelsman et al., 2004; Henderson & Dancy, 2007; Stains et al., 2018), various concerns deter teachers from adopting and adapting AL and ALSs. Reported concerns include the time required for implementation, the use of in-class time, concerns about covering the curriculum, student resistance, doubts about the efficacy of AL, and concerns about teaching evaluations (Andrews et al., 2020; Dancy & Henderson, 2005; Felder, 2007, 2010; Finelli et al., 2013; Froyd et al., 2014; Vuorela & Nummenmaa, 2004). Teachers also report challenges in adapting to ALSs, such as overcoming student distractions and managing a new teaching role (Petersen & Gorman, 2014), lack of departmental support (Dancy & Henderson, 2007; Fagen et al., 2002; Felder & Brent, 1996; Silverthorn et al., 2006; Turpen et al., 2010), students not appreciating or understanding the purpose of the active classes and poor collaboration between peers (Deslauriers et al., 2019).

Professional development can effectively support teachers in this transition (Garet et al. 2001; Sorcinelli 2002). Teachers have expressed the need and desire for professional development to guide them through the implementation process when transitioning to ALSs (Finelli et al., 2013). It is considered helpful to find support by an experienced mentor using classroom observations and discussions with peers.

1.4.2 Opportunities for Adopting and Adapting to ALSs

Active Learning Spaces offer new affordances, i.e., new opportunities for teachers to structure their classes and interact with their students and may also alter teachers' expectations of their classes (Baepler et al., 2014). These new affordances and expectations can enhance existing AL practices (Lasry et al., 2014) and stimulate interest in further AL (Van Horne et al., 2014).

The affordances and expectations from the ALSs change the social context of the classrooms toward fostering improved educational alliances and communication between teachers and students (Baepler & Walker, 2014). Indeed, through AL, teachers may find more fulfilling teaching experiences by helping students appreciate discovering something for themselves (Frank, 2020). Moreover, when teachers enjoy their teaching, this can often lead to better student learning outcomes (Hernik & Jaworska, 2018). In brief, adopting AL and ALSs can be a positive experience for teachers and students alike.

However, there is still a need for institutions to encourage academics to focus more on the effect of teaching on learning. Despite increasing national focus on both AL and ALSs (Meld. St. 16, 2017) and efforts to highlight excellent teaching at NTNU (Raaheim et al., 2020), academics still perceive teaching as undervalued (Graham, 2022). Indeed, Graham reports that since 2019, there has been little significant change in academics' perceptions of their universities' underlying values and priorities concerning rewarding university teaching, i.e., academics view university teaching as persistently undervalued (Graham, 2022). Barriers such as fear of negative student response, lack of time, and lack of support often hinder teachers' adoption of AL strategies (Aga, 2023a; Finelli et al., 2013). Therefore, it remains essential to understand teachers' motivation to adopt and adapt ALSs, using theories like, e.g., the Expectancy-Value Theory (EVT) that considers that teachers' motivation is influenced by both their perception of the difficulty of a task and their perception of the value of the task (Atkinson, 1957; Wigfield & Eccles, 2002). Such research could inform improved faculty professional development and institutional change plans.

1.5 Literature Review

The theme of this thesis is situated in between research topics that have often been viewed separately. An in-depth assessment and evaluation of the use of ALSs require understanding of many related topics, some of which are strongly related to ALSs, such as students' and teachers' challenges using AL, while other topics are less directly related, such as gender differences and math anxiety. Not all references are discussed in equal detail, as this short literature review focuses on seminal works and references relevant to this thesis.

1.5.1 An Introductory Overview

Some noteworthy works that provide an overview of the research themes and other topics related to the research theme are Baepler et al. (2016), Oblinger (2006), Savin-Baden (2007), Amedeo (2008), Dillon et al. (2007), and Mintzes and Walter (2020).

Baepler et al. (2016) present an excellent overview of ALSs for teachers and others wishing to understand the value of ALSs, and they present some of the existing research on these spaces.

Oblinger (2006) focuses on both physical and virtual learning spaces, and looks closer at how learning spaces, technology, and pedagogy can work together to facilitate good learner experiences.

Savin-Baden (2007) discusses the lack of good learning spaces and discussion about these spaces in higher education. Moreover, Savin-Baden focuses on how different spaces have different purposes, such as spaces for writing and spaces for discussion, and how the design of spaces in higher education could be better designed toward the needs of its users.

Amedeo (2008) focuses on how different types of environments can influence people's behavior and takes a broader look at the impact of everyday spaces on their users' activities and choices. For example, the paper discusses how disabilities impact traveling and how different environments influence emotions.

Dillon et al. (2016) focus more on the design of learning spaces and how changing learning spaces can support other educational changes.

Additionally, there is a vast amount of literature on AL and elements related to ALSs. One book that presents a good overview of AL, particularly on student resistance and how to overcome this, is Mintzes and Walter (2020). One of the important works presented in Mintzes and Walter (2020) is the work by Finelli and Borrego (2020), which is further discussed later in the literature review.

1.5.2 An Introduction to ALS Research

One significant resource that presents an overview and highlights the importance of ALSs, and how researching this topic is a complex and emerging field is the book "A Guide to Teaching in the Active Learning Classroom: History, Research, and Practice" by Baepler et al. (2016). Indeed, the opinion presented in the opening statement of the book, "this could be great, or this could be a disaster" (p. 1), resonates well with the overall outlook presented in this thesis, namely that ALSs are not inherently good nor bad. Furthermore, the book draws on many existing studies, some of which are further discussed below.

Brooks (2011), Brooks and Solheim (2014), and Walker and Baepler (2018) present a good starting point for understanding research on ALSs. These papers gradually uncover both how ALSs can be valuable, and that whether ALSs are valuable also depends on other factors. These studies are all centered around exploring ALSs and the qualities associated with these spaces. The beginning of the name of each study, "Space matters…", "Pedagogy matters…", and "Social context matters…", reveals the focus of each paper. Brooks (2011)

found that ALSs can increase student learning outcomes compared to conventional lecturing spaces. Brooks and Solheim (2014) found that pedagogy matters when using ALSs and that ALS use becomes better with AL teaching strategies than with conventional lecturing. Walker and Baepler (2018) found that the social context impacts student learning outcomes differently in the ALSs than in lecturing spaces.

Each of these papers contains important findings and the papers illustrate well how research on ALSs can be done and how the research has developed from asking basic questions about ALSs to more advanced ones. This is pointed out by Bernstein (2018), who suggests that it is necessary to move beyond simply asking if ALSs can be worthwhile, and more toward examining what conditions and circumstances can support the excellent use of ALSs. More so, the stance in this thesis is that not only can such research support improved use of ALSs, but it can also support increased use of ALSs, as it becomes increasingly clear what challenges need to be overcome and how teachers can be supported in overcoming these challenges to benefit from ALSs.

Brooks (2011) presents a quasi-experimental study examining the relationship between learning spaces and student learning outcomes. By having a teacher teach identical sections of the same course in two different learning spaces, it was found that the students who took the course in a technology-enhanced environment conducive to active learning techniques, i.e., an ALS, significantly outperformed their peers in a traditional classroom. While it is reasonable to conjecture from this that ALSs can have a positive value, especially when the teaching strategy includes AL elements, it cannot be taken for granted that the room contributed to the increased student learning outcomes and that the result would be reproduced under different circumstances. Brooks discusses the possibility that the teachers may have already favored the ALSs, which could have impacted the students' results and outlook of their classes in this space.

While Brook's study supports that ALSs can be valuable, it is not necessarily so under all circumstances. Even if ALSs are conducive to increased learning outcomes in some contexts, it is desirable to further explore what these spaces add in support of improved learning and under what conditions these spaces are valuable – or stop being valuable. The spaces may support different groups differently, for example, based on gender, social anxiety, or previous grades. Therefore, it is necessary with similar research to Brooks (2011) under different circumstances, such as with different teachers, types of ALSs, types of AL teaching strategies, and larger sample sets. It is also necessary to supplement such research with qualitative

research to explore which variables may impact the ALS experience and student learning outcomes in this context.

In Brook's study, 41 students in one class and 42 students in another class gave some room for statistically comparing the significance of the results across the learning spaces. Yet, a comparison of a sample of one class in an ALS and one class in a conventional learning space is not sufficient to make a grand statement on the impact of ALSs across different contexts. Indeed, a recurring theme in research of this kind is that the sample of classes is small and may be particular to only one subject, one institution, or one type of teacher. This is not necessarily a shortcoming of the research, but a natural consequence of being in the early stages of researching ALSs. Yet with time, it will be interesting to see more specific and generalizable results related to ALSs.

Brooks and Solheim (2014) build upon the previous study of Brooks (2011). By assessing students' learning outcomes and survey answers relating to their perception of ALSs, Brooks and Solheim (2014) found that ALSs paired with teaching with AL elements, outperformed ALSs paired with traditional lecturing. This finding is an important extension to what was found in Brooks (2011), where it is now clear that ALSs can positively impact student learning outcomes, but more so when paired with AL than with traditional lecturing.

Walker and Baepler (2018) explore how the social context impacts student learning outcomes in conventional lecturing spaces and ALSs. Data for the social context were collected by surveying approximately 2000 students, while student learning outcomes were measured based on course grades from 0-100. Four dimensions of social context were measured. The first, "student-student general", indicated how good the student relations were and how well students worked together. The second, "student as instructor", indicated to what degree a student acted as an instructor toward the other students. The third, "student-instructor formal", indicated whether students and instructors were perceived to be working together, and the fourth, "student-instructor informal", described non-class related relations between the instructor and the students.

While it was hypothesized that a positive measure on all four dimensions would predict increased student learning outcomes, especially in the ALSs, this was only partially true. Indeed, student as instructor was indicative of increased student learning outcomes, but only in ALSs. By contrast, good positive values for the student-student general dimensions correlated with reduced student learning outcomes. Walker and Baepler (2018) discuss the possibility that a good student-student general dimension may be related to distractions as the students have off-topic conversations. Clearly, while ALSs can facilitate better discussion between students,

this does not indicate that all discussions are conducive to increased learning in the subject. Discussions may also work as distractions.

1.5.3 ALSs Impact on Teachers' Habits, Situation, and Outlook

Not only do the ALSs impact the students and their learning outcomes, but it has also been found in several studies that using an ALS changes the teachers and their teaching situation. Taylor (2009) found that using ALSs impacted the teachers' habits by allowing them to do more AL. Baepler and Walker (2014) found that students and teachers developed better relations in the ALSs, which is likely to increase teachers' enjoyment from teaching. This has a bonus effect, as Hernik and Jaworska (2018) found that teachers' enjoyment is a positive predictor of students' learning outcomes. Lasry et al. (2014) found that ALSs can positively impact teachers' outlook on AL over time, yet Carr and Fraser (2014) found that teachers who lecture continue to do so even after trying the ALSs.

Taylor (2009) interviewed teachers using ALSs, and surveyed their students and found that ALSs were perceived to be conducive to making teachers do more AL teaching, increasing the positive effect of the pedagogy on learning, and were perceived to have a positive effect by themselves. Indeed, the findings from Taylor that AL is better for learning in ALSs match the findings from Brooks and Solheim (2014). The finding that ALSs were perceived as positive in themselves links the teacher and students' perceptions in these studies with the quasi-experimental findings from Brooks (2011). Yet, another dimension revealed here is how ALSs were perceived as conducive to making teachers do more AL.

Baepler and Walker (2014) found, through analyzing survey data and interviews, mostly of teachers, but also one focus group interview with students, that ALSs tended to change the social context of the classes taught in these spaces by making the relationships or educational alliances better between the teachers and the students, and among the students themselves. Indeed, it is concluded that it is likely that ALSs are, in general, more conducive to better educational alliances than traditional classrooms. The improved relations between students and teachers in the ALSs may support better education with immediate benefits and lasting improvements over time.

Lasry et al. (2014) set up a quasi-experimental 2x2 factorial design. The factors were on the one hand either ALSs or conventional spaces, and on the other the teachers' beliefs about learning, differentiated between teacher-centered (mostly lecturing) or student-centered pedagogies (AL). The findings here reaffirm that ALSs are most effective with AL teaching

strategies. Yet, beyond this, it was also found that there was a strong correlation between teachers' epistemic beliefs of student-centeredness (their beliefs in AL teaching strategies) and the student learning outcomes in their courses. Lasry et al. (2014) pointed out that the evidence suggest that ALSs are most effective when the teachers use AL teaching strategies and believe in these strategies. Intuitively, it makes sense that simply teaching with AL in ALSs is not enough for excellent results and that the teachers also ought to believe in the spaces and the teaching strategies they are using.

Carr and Fraser (2014) point out in their overview that despite the huge cost of developing ALSs, the full potential of these spaces is not realized as lecturers who mostly lecture continue to do so in ALSs. Anecdotes also indicate that many teachers do not change their teaching practices and continue to lecture even if they are in ALSs. Carr and Fraser (2014) further suggested that this can be resolved through professional development and institutional change remedies. They found evidence that the ALSs may change teachers' belief in using AL teaching strategies over time toward believing more in AL and doing more AL. The findings from Carr and Fraser (2014) and Lasry et al. (2014) may at first seem contradictory, in that some teachers change in the ALSs, but others do not. It may be that teachers with a strong preference or belief in lecturing do not change regardless of space and that the ALSs may further solidify their belief in lecturing if such a belief also prevents them from having successful ALS classes. Furthermore, teachers with a more curious outlook toward AL may have more positive experiences in the ALSs, which may inspire further use of AL and ALSs.

Regardless, the four articles discussed above by Taylor (2009), Baepler and Walker (2014), Lasry et al. (2014), and Carr and Fraser (2014) highlight that using ALSs impacts teachers and may contribute to changing their outlook on teaching and teaching practices over time. This may, in turn, further benefit their teaching practices and, in turn, improve their use of ALSs over time.

1.5.4 ALSs and Emotions

Also related to ALSs are studies of teachers' and students' emotions. Frank (2020) presents a reflection on how engagement and joy are central elements to benefit from the ALSs, and that a pitfall to using AL and ALSs is not letting the students experience joy in this setting. A lot of the joy students experience in the AL setting is discovering things for themselves, and Frank discusses the possibility that telling students things is insufficient for a good education. For the

teachers, witnessing the students' enjoyment from AL can make it more enjoyable for themselves to practice AL.

Hernik and Jaworska (2018) share reflections similar to Frank's (2020), that enjoyment and humor can positively affect learning, memory, and social behavior. Their study presents both a literature review on emotions, teaching, and learning, and an experiment including four groups of students, examining their level of satisfaction and knowledge. They found that students memorized more during relaxing and enjoyable lectures than they did in rigid and boring ones. Also, after enjoyable sessions, more students reported being satisfied with the classes and claimed to have learned more than the students in less enjoyable sessions. Yet, importantly, it is also noted that an excess of jokes or "distractions" can be a negative factor which may be distracting.

1.5.5 AL and ALSs

An essential aspect of succeeding with ALS use is also succeeding with AL, and a frequently mentioned challenge of succeeding with AL is overcoming student resistance to AL. Elements related to AL are discussed in the articles below.

Finelli et al. (2013) state that effective teaching practices (AL) within STEM are underutilized. In order to encourage more AL use, they set out to identify hindrances to teachers in using AL in order to inform professional development supporting teachers using AL. The Expectancy-Value Theory (EVT) revealed many moments that hindered teachers from adopting AL, such as concerns about lack of time, easily available information about effective teaching practices, and more.

Petersen and Gorman (2014) published a reflective paper that points out strategies that can be used to address common challenges when teaching in an ALS that they have encountered when talking with teachers as teaching consultants. One challenge is that the technology in the ALSs can be overwhelming and that teachers must shift their teaching strategy to use more AL, as the teacher is no longer the focal point as in lecturing. It is, for example, suggested that teachers present their teaching philosophy and choice of learning spaces early and directly to the students, so that the students also can understand the choices that have been made. Asking for student feedback to include the students in the process of what is going on in the learning space is also suggested.

Froyd et al. (2014) surveyed teachers' use of research-based instruction strategies among teachers that had recently taught STEM classes, more specifically in engineering

science courses. It was found that many teachers who had tried different forms of AL or research-based instruction strategies had discontinued their practices. Such discontinued use of AL highlights the need for a good understanding of teachers' challenges as they use or seek to use AL. Some barriers the teachers mentioned about AL use were limited class time to do AL segments, limited preparation time, a perceived lack of evidence supporting AL, and other elements such as administrative challenges.

1.5.6 Student Resistance to AL

As presented later in the results of this thesis, a great deal of the teachers' and students' concerns were related to engagement and student participation in the AL elements of the classes. Indeed, it appears necessary to succeed with AL and student engagement to succeed with ALSs. A frequent concern related to AL use that resonates with these findings is overcoming student resistance. Tharayil et al. (2018), Finelli et al. (2018), Finelli and Borrego (2020), Deslauriers et al. (2019), and Andrews et al. (2020) further discuss student resistance.

Furthermore, it may also be the case that student resistance is more of a challenge in mathematics or statistics than in some other subjects. While not extensively discussed, this is alluded to in the third paper.

Tharayil et al. (2018) explored what strategies teachers used to reduce student resistance to AL by observing classrooms, interviewing teachers, and surveying both students and teachers. They found that most of the teachers' strategies could be categorized into either facilitation or explanation strategies. Three explanation strategies were mentioned: explain the purpose, explain the course expectation, and explain activity expectations. While eight facilitation strategies were mentioned, which included but were not limited to assuming an encouraging demeanor and designing activities for participation.

The work by Tharayil et al. (2018) demonstrates that there are many strategies for teachers to use to reduce student resistance to AL. Yet, most teachers only used a selection of these strategies. It is not certain that it is necessary or even better to use all the strategies, and it may be that the effect of each strategy depends on the teacher and how the strategy itself is employed. It is necessary with further research to learn more about how to employ these strategies for the best outcomes of using ALSs.

Finelli et al. (2018) acknowledge that student resistance to active learning can be a challenge in order to have successful AL classes. Their study is based on a student survey conducted across 18 introductory engineering courses that examined students' perceptions of

their own and the teachers' behavior in the classroom. The survey particularly focused on how students perceived teachers' strategies in the classroom and if the choice of strategy influenced the reduction in student resistance to active learning. The study divides the teachers' strategies into two categories, explanation and facilitation. This is similar to the categorization made by Tharayil et al. (2018). One example of explanation strategies the teachers used to reduce student resistance to AL was to clearly explain the activity's purpose and to discuss how the activity was related to the students' learning. A facilitation strategy could be to invite students to ask questions about the activities and confront students who were not participating. While the study suggests that explanation and facilitation strategies can effectively reduce student resistance to AL, the student survey suggests that facilitation strategies were the most effective.

In their study, Finelli and Borrego (2020) examined the literature on students' affective responses to AL and surveyed the students about student resistance. Three different types of student resistance were found: whether students participated in activities, the extent to which students distracted themselves and their peers, and how students evaluated the course and the teacher at the end of the semester. Students were rarely found to be confrontational in their resistance to active learning. Again, Finelli and Borrego (2020) found that strategies employed by the teachers could indeed reduce student resistance. The two categories of such strategies, as mentioned before, facilitation and explanation, were identified as meaningful categories of strategies. However, a third category of strategies to reduce student resistance to AL was also identified. This third category was named planning and indicated how planning before the class could help. Examples of *planning* elements were using feedback from students to design a new activity, reflecting on what did not work on past activities and improving on those, and designing activities toward increasing student engagement.

The work of Finelli and Borrego (2020) can be built upon by investigating the role such strategies can have in professional development for teachers using AL. In addition, the relation between instructors' use of strategies, students' affective responses toward these strategies, and student resistance outcomes should be explored.

Deslauriers et al. (2019) reaffirmed that student learning outcomes were better with AL than with lecturing, even when the instructors made no effort to persuade the students of their method. The study randomly assigned the students to different classes, and the class content and handouts were identical. Interestingly, students' perception of learning was higher in the lecturing classes than in the AL classes. This discrepancy between students' perceived learning and their actual learning indicates that evaluating AL or ALSs only on student perceptions of

learning is problematic. The result suggests that an excellent lecturer can create a lecture that creates such a high sense of learning in the students that they would prefer the lecture above AL, even when they actually learn less.

Deslauriers et al. (2019) discuss that the increased cognitive effort and challenge reported by students in the AL classes often is taken by the students as a sign of poorer learning. Such misunderstandings in the students would likely lead to low motivation for participating and engaging with AL elements. Therefore, it is important to discuss strategies that support students in discovering the increased learning outcomes from AL, and to support engagement with the learning activities presented to them. While some strategic suggestions have already been presented by Finelli and Borrego (2020), Finelli et al. (2018), and Tharayil et al. (2018), the paper by Deslauriers et al. (2019) stresses how teachers can talk about the aspect of how the increased cognitive load on the students in the AL can be perceived as negative, but really should be perceived as positive.

In their study, Andrews et al. (2020) present an important result and discussion point, namely that they found a disconnect between the teachers' perceptions of their students' attitudes toward AL and the students' self-reported perceptions toward AL. The teachers were reported to perceive the students resisting AL to a greater degree than what the students themselves reported. In fact, a large portion of the students remained quite positive toward AL. This finding is important as teachers' fear of student resistance and poor evaluation of their work by students, due to their perceptions toward AL, can dissuade teachers from adopting these evidence-based practices. The findings of Andrews et al. (2020) suggest that such fear is at least partly unfounded.

The data for the study of Andrews et al. (2020) were collected through surveys of instructors and students, as well as based on classroom observations. A total of 27 STEM teachers were surveyed at ten different institutions across Texas, and while an overview of the teachers' characteristics is presented, what is less discussed is the amount of experience the different teachers had with AL. It can be speculated that if it is the case that some, most, or even all of the teachers had experience with using AL, their students' perceptions of their teaching would be more positive than it would be for teachers who are transitioning to using AL and have less experience. Therefore, a similar study should be designed to examine whether these findings would be consistent among different groups of teachers based on their experience of using AL.

1.5.7 ALSs and Gender

While only peripherally related to this thesis, an emerging area of research is the research on how ALSs impact genders differently. The three following papers Sullivan et al. (2018), Aguillon et al. (2020), and Ballen et al. (2018), discuss how ALSs impact students differently based on gender. These papers highlight well how ALSs can impact students and student groups differently. Additionally, they highlight how many sub-fields of ALS research are only recently developing, and that better understanding of such sub-fields can be used to support better and more equitable use of ALSs.

Sullivan et al. (2018) examined how different ratios of women in an ALS in biology impacted the learning experience. It was found that groups performed better the higher their ratio of women was. Indeed, women positively influenced overall performance, sense of social belonging, and peer evaluations. This highlights another dimension, the importance of retention of women in STEM, that female rich groups benefit everyone.

Yet, more specifically, it also means that ALSs may be more successful depending on the students and that women bring qualities to the ALSs that make these spaces more valuable. A natural follow-up to this research is to learn more about what women do to make the ALS experience better for everybody – that perhaps the male students (and teachers) can learn from this.

It is speculated by Sullivan et al. (2018) that the increased benefits from groups with women were due to increased group cohesion in such groups, which in turn may reduce barriers to discussion and increase students' learning outcomes.

Ballen et al. (2018) found that with increased class size, women's exam results dropped. These results were not specific to ALSs, but that class size may impact different groups differently is a reflection that could be further highlighted in ALS research.

Aguillon et al. (2020) note that while evidence is increasing that ALSs can be beneficial, these spaces are not equally beneficial to all participants. They may, for example, impact women and men differently. In this study, it was found that women benefitted less. This is in many ways surprising given the findings in Sullivan et al. (2018), yet it is explained that in AL segments, men often participate more and that there, therefore, is a need for inclusive strategies employed by the instructor. Indeed, it is unfortunate that women make everybody better during group work while they themselves benefit less than men.

In addition, regarding the general impact on AL and ALSs, the findings in Sullivan et al. (2018) and Aguillon et al. (2020) indicate that gender and student roles matter and good group cohesion and group discussions appear to be impacting the quality of the ALSs. The

findings also indicate that a more advanced concern for teachers using ALSs may be that they need to use strategies to ensure equitable participation between the students, both considering gender, but also other variables like social introversion, in order to work toward ALS benefitting all students.

1.5.8 ALS and Social Anxiety

Cohen et al. (2019) point out that there is little research on how students with social anxiety experience AL. Their findings also indicate that students experiencing social anxiety experienced increased discomfort toward AL in the ALSs and that the combined effect of experiencing high social anxiety and high AL discomfort was correlated with lower course grades. Yet, there may be strategies to use to reduce the social anxiety and AL discomfort that students experience. Indeed, future research on the topic is necessary to explore the possibilities for identifying strategies that support improved student learning outcomes for all types of students in the ALSs. Overall, this research should increase awareness that AL and ALSs may benefit less, or even harm, certain types of students.

1.5.9 ALSs and Professional Development

Johnson et al. (2021) present a case study of one ALS used by teachers in STEM courses, experienced with AL. The data consist of teacher interviews and classroom observations, and nine strategies were identified as used to facilitate for AL. The results highlight how ALSs can be conducive to some of these strategies, such as teachers walking around the learning space and interacting with the students. It is also suggested that the ALS supported the teachers in developing a better routine for AL and making the AL elements more engaging for the students.

The study concludes that ALSs are valuable and should be used more broadly, yet it is essential that the development of such spaces also is accompanied by professional development in order to support teachers in using these spaces.

Nelson et al. (2023) interviewed instructors who used ALSs. It was found that instructors who had participated in a professional development program to support their use of AL experienced fewer hindrances and difficulties in using ALSs.

Based on these results, it is crucial to continue developing good professional development programs for teachers, and AL and ALSs are two areas where teachers often feel

challenged. Continuing research toward better understanding and informing professional development on how to support better teachers who transition to AL and ALSs are essential measures to improve education.

1.5.10 Final Remark on the Literature Review

The research presented here makes it clear that there is increasing evidence that ALSs can support increased student learning outcomes, increased student motivation, and a positive change in teaching strategy in teachers. These results support that pursuing further use of ALSs is worthwhile.

Yet, there are still many open questions related to ALSs, such as why and how ALSs support improved education, what are best practices in the ALSs, and what are excellent ways of getting new teachers and students to want to use ALSs and overcome the challenges they face in these spaces. One element yet to be widely researched is what is examined in this thesis: how teachers and students who are new or mostly new to ALSs experience using these spaces.

This thesis focuses on the transition process, as overcoming the challenges and ensuring a good experience for students and teachers new to ALSs are essential for their continued and successful use of these spaces. Understanding their perspective is an essential aspect of a broader understanding of ALSs. Additionally, research on AL or ALSs often examines classes where the teachers already are experienced with using such spaces. The experiences of teachers new to and experienced in these spaces are not necessarily the same. Also, there are many different contexts to explore, and examining them will take time. In this thesis, the context of Norwegian higher education has been examined further.

1.6 Situating the Research

As will be established in this thesis, when one looks at ALSs, it also becomes necessary to look at many other elements. The view here is that ALSs have no intrinsic value independent of the chosen teaching-learning design. This is highlighted in Sections 2.1.3 and 3.3. Therefore, when looking at ALSs it is also necessary to look at other elements that make ALS use meaningful. The more elements that are examined, the more comprehensive and realistic becomes our understanding of the value and use of such spaces. For example, by looking at teachers and students in the ALSs, one can gain a deeper understanding of the ALSs. Further understanding can be achieved by examining how the subject matter or institutional relations impact teachers

and students in the ALSs. However, the more elements influencing the ALSs that are examined, the more complex the study becomes.

Initially, the motivation for researching ALSs was that while such learning spaces had been developed at NTNU with ambitions for pedagogical development, there was little expertise and little research on the value and use of such spaces within the university. Furthermore, a large-scale property development project, the Campus Development Project was in process at the university, where several new buildings were planned to be built by merging two campus locations into one (NTNU, n.d.-a). As there would also be new learning spaces, it was discussed how many and what types of ALSs should be designed in the buildings to come.

Also, TettPÅ project was an essential stakeholder in moving the thesis towards focusing on ALSs in order to develop more knowledge on ALSs, as this could positively influence the campus development project (NTNU, n.d.-a, n.d.-b).

Therefore, exploring what quality is, or could be, in the ALSs was considered desirable and beneficial. Indeed, initially there was a very broad and ambitious research goal, as it was motivated by the institutional need for expertise among the university's staff on ALSs on the design and use of ALSs.

The Interactive Action Research (see Section 2.2.3) (IAR) outlook was adopted as it allowed for exploring how teachers transitioned to the ALSs while simultaneously supporting them in this transition to overcome basic obstacles. This research design allowed for exploring a situation similar to what may appear later when many new ALSs are developed, allowing many new teachers to use ALSs at the university.

The thesis can be viewed from a special case perspective, and a general case perspective. In the special case, the thesis can be viewed to be about ALSs, specifically within the cultural context of a Norwegian university and a mathematics and statistics teaching and learning environment. The research topic highlights the elements related specifically to ALSs, such as challenges for teachers interested in transitioning to the ALSs. In the more general case, the thesis can be understood as highlighting relations between elements such as teachers, students, content material, teaching design, pedagogical strategies, and more. This view highlights that the insights here are relevant to teaching overall, even when not necessarily in ALSs.

1.7 Research Questions

With some background on ALSs established, it is an opportune time to explore the thesis' aim and research questions. The overarching aim of the thesis is to explore factors and conditions linked to the efficacy of ALSs. More specifically, to explore the value and challenges of ALSs for teachers and students in mathematics and statistics transitioning to these spaces.

This aim is explored through the teachers' and the students' perceptions. Some motivating factors for choosing this aim were:

I) As stated earlier, there is a national and institutional interest in understanding, developing, and efficiently using ALSs (Meld. St. 16, 2017; NTNU, 2019a, 2019b, 2023c). Examining these spaces and understanding their value and challenges in a cultural and local setting is vital to investigate whether the value of ALSs found in the literature is relevant also to the local context.

II) Moreover, as there has been little research on ALSs at NTNU, it is therefore of interest with an exploratory study in this context. For a more in-depth explanation on the benefits of qualitative research see Section 2.2.1 Motivation for Qualitative Research.

III) The transition process is a potential bottleneck in using ALSs effectively. It is indicated by research that while ALSs can improve student learning outcomes from AL, there is no guarantee that all ALS use will benefit all its users (Baepler et al., 2016). Thus, it is essential to better understand and support teachers and students using ALSs. Especially, the transition process, where teachers and students alike are exposed to the ALSs for the first time in a higher education context is a vulnerable stage that is important to understand.

IV) This research was situated with a specific interest in how the newly designed ALSs at NTNU impacted the quality of mathematical and statistical education. It would be interesting to conduct similar research independent of subjects or with a focus on another subject. Also of note is that mathematical and statistical courses are essential at NTNU, Norway's largest higher education institution, with many of its over 40 000 students studying in STEM fields (NTNU, n.d.-b).

The challenges and value of ALSs have been explored through three studies reported in Papers I, II, and III. Paper I examines the teachers' perceptions of ALSs as they transitioned to these spaces. Paper II examines the students' perceptions of their classes conducted in the ALSs, and Paper III examines any relations to how teaching and learning of mathematics and statistics were impacted by the use of AL and ALSs. In brief, the overarching aim of the thesis can be better understood through the papers' research questions, as presented in Table 1.

It should be stressed that the papers report on perceptions about and reactions to the transition. An early ambition to investigate the design properties of the Active Learning Spaces themselves, and how the specific design interacted with different teaching and learning activities was abandoned in favor of the present research focus. This leaves an interesting field for further research at a later stage.

Table 1. The research questions as posited in the three papers presented in this thesis.

Paper	**Research Questions**
I	(1) What do the teachers perceive to be significant challenges to overcome when transitioning to ALSs? (2) What did the teachers do to overcome the challenges? (3) How do the teachers perceive that their motivation and their challenges mutually affect each other?
II	What factors did students perceive necessary for a good ALS learning experience?
III	What challenges do teachers experience when using ALSs, specifically in the context of mathematics and statistics?

Through answers to these research questions, one can learn more about the use of ALSs and their limitations and opportunities, which should be valuable for supporting teachers that are transitioning towards more use of active learning designs. The teachers' and students' perceptions from the first two papers may contribute to changes in how teachers can act in the ALSs, while the third paper may inspire the development and design of better suited tasks in mathematics and statistics for the ALS setting. Furthermore, discussing how such knowledge can be used to implement changes that can support teachers and students to use AL and ALSs effectively is vital. Essential to such improved education is continuing research and implementing changes in professional development and institutional change plans (Finelli et al., 2018).

2 Methodology

The methodology chapter provides an overview of the models, frameworks, theoretical works, methods, research design, data collection, and data analysis used in this study. Some of the sections are explored more in depth in the papers.

2.1 Models and Framework

The Expectancy-Value Theory (EVT) and the Approach-Avoidance Theory (AAT) have both been used as lenses to highlight the teachers' and the students' motivation during the transition process. It quickly became apparent to the researcher that beyond reflecting on tasks and mathematical and statistical details, the participants in the study reflected that engagement was a crucial challenge to overcome to benefit from the ALSs. Moreover, to have good engagement, it was necessary that the students were motivated to engage, and that the teachers were motivated to adapt strategies to engage the students. The EVT and the AAT were useful lenses for discussing and understanding the teachers and students. Moreover, the Interaction Equivalency Theorem (IET) has shaped the researcher's outlook on the value of learning spaces, further explored in Section 3.3.2.

2.1.1 Expectancy-Value Theory

The Expectancy-Value Theory (Atkinson, 1957; Eccles et al., 1998; Wigfield & Eccles, 2002) is a framework for categorizing motivation. This theory was used to better understand the teachers' motivation to transition to the ALSs, how the challenges in Paper I impacted the teachers' motivation, and how the teachers' motivation to transition to the ALSs impacted their view on the challenges presented in Paper I.

According to EVT, an individual's motivation for a task depends on two categories, the *expectancy* of accomplishing the task, and the *value* attributed to achieving it. The expectancy category is further divided into two sub-categories:

i) *Ability self-concept,* which is the individual's belief in mastering a task.
ii) *Task difficulty*, which is the individual's perceptions of the difficulty of accomplishing the task.

The value category consists of four sub-categories:

i) *Attainment value*, the subjective view on the importance of doing well with the task.
ii) *The intrinsic value*, the anticipated enjoyment from engaging with the task.

iii) *The utility value*, the usefulness for future plans from engaging with the task.

iv) *The cost*, i.e., the perceived effort, emotional cost, and loss of opportunity due to engagement with the task.

Together these categories and sub-categories offer a more detailed framework for understanding of the teachers' motivation as they transition to the ALSs.

2.1.2 Approach-Avoidance theory

The Approach-Avoidance Theory (AAT) may be said to describe conflicts between internal motivation forces within an individual. This theory states that people will likely approach or avoid stimuli, situations, or behavior based on their perceived value and appeal (Carver, 2006). When a situation is perceived partly as positive and partly as negative, a conflict can arise between approaching and avoiding the situation. The interplay between such approach and avoidance interests gives rise to three different motivational conflicts, which are *approach-approach conflict*, *avoidance-avoidance conflict*, and *approach-avoidance conflict*. Approach-approach conflicts are conflicts between two potential gratifications, while avoidance-avoidance conflicts are conflicts between two potential threats. Finally, approach-avoidance conflicts are conflicts between a potential gratification and a threat of the same action (Corr & Krupić, 2017; Kiknadze & Leary, 2021).

Paper II uses the approach-avoidance conflict perspective to discuss and better understand why and how students engage with the active elements in their ALS classes.

2.1.3 Interaction Equivalency Theorem

Despite increasing evidence that active learning, and particularly active learning performed in ALSs, can enhance student learning outcomes, it has been argued that no single medium supports the educational experience in a way that is superior to all others (Anderson, 2003). This view is aligned with the Interaction Equivalency Theorem (IET) which states that:

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student–student; student–content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience. (Miyazoe & Anderson, 2010, p. 1)

Indeed, while active learning offers opportunities for student-student interaction, such interaction is not guaranteed to be of high quality.

This supports the outlook in this thesis that AL and ALS use can, but does not have to, provide an improved learning experience compared to, e.g., traditional lecturing. This

perspective is kept in mind when examining teachers' and students' perceptions of transitioning to the ALSs. That is, the researcher is aware that there are elements in AL and ALSs that are not necessarily better or worse than lecturing in conventional lecture halls, but simply different. By bringing out these differences by focusing on the perspectives of teachers and students transitioning to ALSs, it should be possible to support educational improvements on how to use different learning spaces.

The IET further influenced the researcher's reflections and outlook on ALSs, and also the development of a suggested model that can be used to examine how well ALSs are used. This is further explored in Section 3.3.

2.2 Methods and Research Perspective

2.2.1 Motivation for Qualitative Research

While there are many elements related to learning and education, in this thesis only elements strongly related to AL, ALSs, mathematics, and statistics will be examined. There is a need for both qualitative and quantitative research, which can support research on the use of AL, and ALSs. While quantitative research is vital as it excels in precise measurement and statistical analysis, it can be restrictive on what factors or variables are available to measure. Qualitative research offers the potential for deep understanding, contextual insights, theory development, participant empowerment, and flexibility, where quantitative methods are problematic.

One anecdote that supports the importance of qualitative education research is that of a teacher trying to use ALSs, and after only changing the learning space and nothing else, i.e., the teacher still did conventional lecturing with little or no student activities except a few questions to the whole class, the teacher experienced that the students did not engage, listen, participate, or learn more in his class. Therefore, the teacher concluded, a conclusion he gladly shared with his peers, that ALSs did not work and had no value. In this anecdote, the teacher lacked an understanding that the value of ALSs depends not only on the space but also on how the space is used. The anecdote offers an example where qualitative research can help unveil what variables are related to good and bad ALS use. Such research can be used to later set up quantitative research approaches, where the outcome of the qualitative research is tested.

2.2.2 Qualitative Methodology

A qualitative methodology with a phenomenological approach was adopted to investigate the experiences of teachers and students related to ALSs. Using the data collected in Table 2, a clearer insight was gained into the perspectives of the research participants, highlighting aspects on ALSs (Kvale & Brinkmann, 2009; Postholm, 2005; Schutz, 1972).

A distinct characteristic of the chosen approach was the researcher's closeness to the interview subjects, particularly the teachers. This closeness allowed for a more in-depth interpretation of the interviewees' perceptions. Such proximity can support a deeper understanding of the phenomena under examination (Lund & Haugen, 2006) and promote holistic comprehension (Johannesen et al., 2016). The researcher aspires to form a comprehensive image of the participants' viewpoints by focusing on the specific research topic. Qualitative research positions the researcher as the most critical research instrument due to the necessity of maintaining an interpretative role during the research process (Postholm, 2005).

2.2.3 Interactive Action Research

Action research is not limited to a specific method but signifies an approach encompassing various methods (Svensson et al., 2017). Action research is often used in educational research to enhance, change, and describe educational practices (Elliot, 1999). Thus, action research impacts the participants throughout the research project, as it aims to transform how the practitioners practice, comprehend their practice, and the conditions under which they carry out their work (Kemmis, 2009). There are several forms of action research, but interactive action research (IAR) has been selected here as it highlights the equal relationship between researchers and practitioners. In this relationship, the researcher contributes with the experience from the research field and works to develop the field of practices while researching this practice. Furthermore, the IAR perspective encourages the researcher to establish a positive connection with the teachers that supports getting in-depth data and, among other aspects, strives to reduce bias in the interview data. In addition, IAR allows the researcher to inquire about the practitioners' opinions, closely follow the practitioners throughout the research period, and offer input to the practitioners to support the change in practice. In the setting of this thesis the practitioners were the teachers.

The choice of an approach according to IAR allowed the researcher to influence the teachers and the research context, which made the research project possible. This is further explored in Section 2.3.2 and 2.3.3.

2.2.4 A Phenomenological Perspective

The phenomenological perspective focuses on individuals' experiences, i.e., how they perceive and interpret their situation (Kvale & Brinkmann, 2009). This perspective supports the researcher in understanding social phenomena from the participants' viewpoint and obtaining a deeper understanding of the current topic under study, e.g., by observing participants in their natural environments (Johannessen et al., 2016). However, the researcher's theoretical and personal perspective influences the research, making transparency about this influence crucial to presenting an honest perspective on the value of the research. This transparency is shown by outlining the researcher's scientific perspective and acknowledging subjective choices made in the study.

2.3 Research Design

This section presents how the research was conducted, as well as a brief explanation of the ALSs that were used by the teachers and students in the research. The papers address more in detail the individual design for each of the papers.

2.3.1 The Active Learning Spaces

In my research, the use of two ALSs was observed, R2 and SMIA (see Figure 1). R2 can take 160 students, has a tiered level, and was used by three of the four teachers. SMIA can take 50 students, has a flat floor, and was used by one of the teachers. Both spaces facilitated student interaction through tables designed for student groups of about six to seven students. In addition, the spaces had educational technology, such as a shared physical writing surface, a shared digital surface, and a microphone for each student group. There was also Wi-Fi for the students to use and a control panel to manage different digital surfaces available to the teacher (NTNU, 2022a, 2022b).

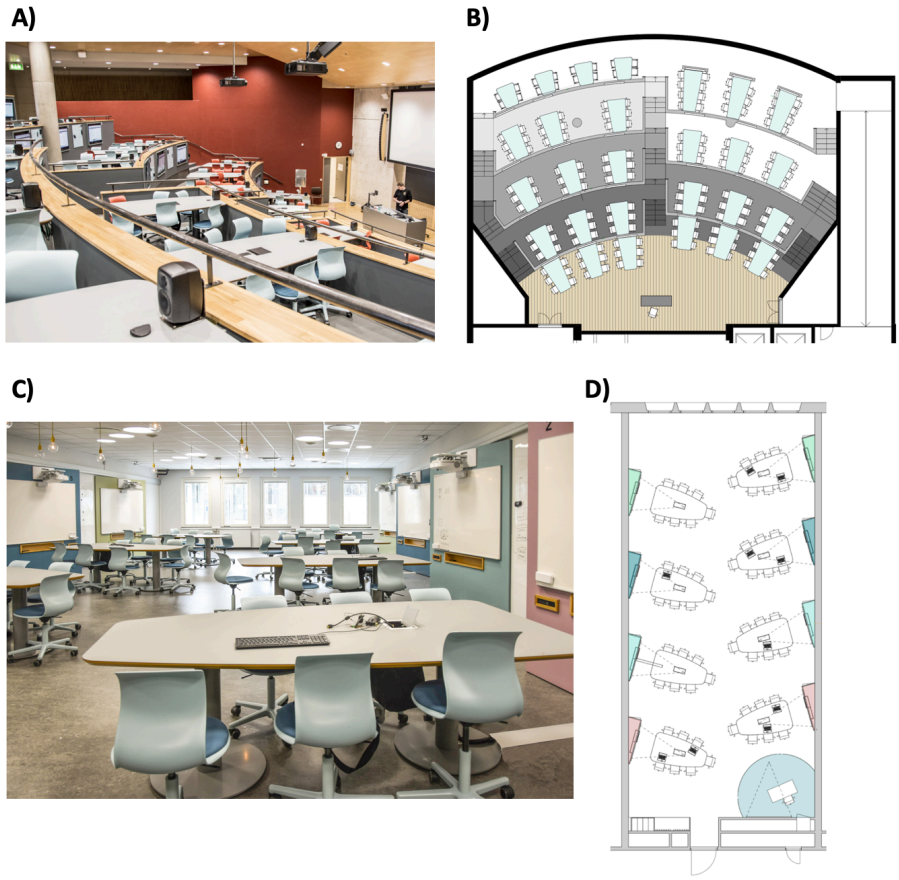

Figure 1. Illustrations of R2 (panels A and B) and SMIA (panels C and D), provided by Eggen Arkitekter AS.

2.3.2 Preparation for the Research

The teachers who transitioned to ALSs were expected to be highly self-motivated to transition and to be willing to use ALSs voluntarily. Therefore, an initial stage of the research project consisted of seeking out teachers in mathematics and statistics willing to use ALSs, and to enter a partnership with these teachers to explore the value and challenges of these spaces.

Interaction between the researcher and the teachers was necessary in order to additionally motivate the teachers to transition to ALSs and ensure that the transition process overcame some fundamental challenges surrounding the use of AL teaching methods and the potential benefit of ALSs. It was also important not to overly influence the teachers as the most realistic and beneficial insights might come from teachers less impacted by the researcher. Only after the researcher had encouraged the teachers to share their thoughts and feelings on a topic,

and if the researcher was asked to, or the teachers otherwise expressed interest, did the researcher share findings and ideas from relevant literature and theory to contrast or highlight a point. It was important to let the teachers speak first and discuss among themselves to avoid overly influencing them. After the researcher had shared some new information, the teachers were typically asked what they thought about the new perspective, to get a deeper understanding of the teachers' outlook on teaching and the transition process to the ALSs.

The research design was inspired by IAR (see Section 2.2.3), a research methodology that seek not only to describe the research topic but also encourages the researcher to influence the research process in order to look at changes and transitional processes (Postholm, 2007). It should be emphasized that while this can be a strength of the IAR methodology (Postholm, 2007), care needs to be taken as there is a potential challenge that the approach risks adding additional subjectivity to the research.

Most importantly, the IAR methodology allowed the researcher to encourage the teachers to transition to the ALSs and guide the researcher into entering a partnership with the four participating teachers to explore their perceptions about the challenges of transitioning to the ALSs. Using IAR inspired a strong encouragement from the researcher to the participants to communicate that the research environment’s core purpose was to make the teachers comfortable and to be of benefit to their teaching; and that only second to this would any research be conducted. These measures were taken to secure a safe environment where the teachers could share their perceptions freely.

The teachers and the research context were influenced in the three following ways:

1) Before the teachers decided to use the ALSs and join the study, the researcher explained how AL and ALSs could benefit their teaching. It was made clear that some data collection was essential to the project, but that they as teachers would always have the final say in what to do, how to teach, and how to interact with the researcher. Moreover, the researcher offered to assist them in improving their teaching and teaching methods and it was made clear that the researcher would be available throughout the transitional phase for them to lean on if they so desired. This support was emphasized to encourage the teachers to join the study, and to support and benefit their transition to ALSs, as professional development has been pointed out to support such transitional phases (Garet et al., 2001). Support was also given to overcome any simpler obstacles that the teachers might encounter in the process of transitioning, such as not fully understanding

the purpose of AL. This would allow the teachers and researcher together to explore the challenges and value of ALSs encountered in the transitional process.

2) Once the teachers agreed to be part of the project, the researcher influenced the room selection process to guarantee that teachers were assigned to the ALSs.
3) During the study, the researcher continued to offer input to the teachers on ideas and advice to benefit their ALS use and transition process. Moreover, the teachers were strongly encouraged to discuss AL and ALSs with each other. These measures were intended to support the teachers in their transition to ALSs and to uncover any deeper challenges or benefits of using ALSs.

2.3.3 The Researcher's Influence on the Teachers

A worry teachers had early on before they started using the ALSs was how to design their teaching strategy. The teachers expressed concern that transitioning to teaching methods such as flipped classroom or problem-based learning would demand an immediate, extensive change to their teaching designs. Such a big leap in teaching strategy was considered daunting due to several reasons, such as the teachers were not quite sure how to start developing a new teaching strategy. Additionally, the teachers also expressed reluctance to adopt such a teaching strategy as they were uncertain of how time-consuming the process would be, which was further compounded by the apprehension of committing to this strategy for a longer period of time, especially considering the time they anticipated needing to develop it. The teachers were also unsure whether or not this change in teaching strategy would result in better student learning outcomes. Finally, the teachers expressed a fear that some peers, especially if the transition was unsuccessful, would disapprove of the deviation from conventional teaching methods. Therefore, early in the project, the teachers sought guidance on potential AL methods and how to teach within the ALSs.

While the researcher did not intend to guide the teachers toward a specific teaching strategy, the researcher eventually gave some input on teaching strategies due to the teachers' strong and frequent concern about developing a new AL teaching strategy fitting the ALSs. The researcher informed the teachers on teaching strategies such as problem-based learning, flipped classroom, and peer instruction. Other strategies for engaging the students, such as grouping them in varying ways, using diverse tasks, and a Student Response System (SRS) (Draper & Brown, 2004; Nicol & Boyle, 2003), were also discussed. When explicitly solicited by the teachers, the researcher provided a viewpoint on issues related to the ALSs. The

researcher stressed that such viewpoints were subjective opinions and that other perspectives were available.

The input offered was given in the context that the teachers were new to AL and ALSs, and that they expressed that it was daunting or at least not so motivating to change teaching strategy entirely. They also asked whether there were meaningful ways to use AL in the ALSs that would entail only minor changes to their teaching strategy for the first semester(s). In this context, the researcher mentioned that one way of not changing the teaching strategy entirely was to keep lecturing segments but intersperse traditional segments with AL segments.

It was argued that such AL segments could have three core benefits. Firstly, AL segments could work as breaks from the lecturing segments and benefit the students by giving them time to process the information presented during the lecturing segment. Indeed, it has been argued that limited cognitive capacity makes lecturing for longer segments suboptimal (Cooper & Richards, 2017). Secondly, the teachers could leverage student discussions, facilitating for the students to learn from each other. It has been reflected that students can be quite good at explaining concepts to peers as they overcome the challenge called *the curse of knowledge* (Pinker, 2014). The term *the curse of knowledge* suggests that with time it can become more and more difficult for an expert to understand the challenges novice learners face as they try to learn the domain of the expert. It is reflected that when one becomes increasingly proficient with a subject, there is a risk of becoming increasingly oblivious to the challenges and misunderstandings that students may face in understanding the new content. Students who just understood the subject content are, however, often aware of possible misunderstandings and, therefore, can be good at communicating a pedagogical explanation to peers. Thirdly, by pairing AL segments with an SRS, the teachers can get immediate, constructive, and efficient student feedback. Feedback in the simplest form can inform the teachers on the percentage of correct answers, while more advanced feedback could indicate the students' specific misunderstandings. Such feedback could be used by the teacher to direct their instructions towards any issue that the students need the most support in understanding.

However, it was also stressed that while using lecturing segments paired with AL segments, additional changes can be made to the teaching strategy. Such input as just elaborated on was the most subjective input that the researcher gave the teachers, in the sense that the researcher chose which research and which results to share with the teachers. However, it is worth pointing out that the researcher expressed strongly that by no means should the chosen research should dictate how the teachers would choose to teach. Instead, it was stressed that there were many outlooks on how to use AL segments, and it was encouraged that each

teacher should find their own approach and explore different teaching strategies that might fit them. In brief, the input given was provided because the teachers asked for it and guidance was promised, and it was a real possibility that the teachers would not participate, or not have a positive outlook on AL and ALSs, if they were not given suggestions for how to teach with AL in the ALSs without making bigger changes to their teaching strategy.

The impact of the researcher's influence may or may not have directed the research in a different direction. There is no sure way of knowing this, which is a recognized risk by action research and the chosen IAR methodology. It does not mitigate the value of such research; rather, it necessitates running similar research projects to try to reproduce or otherwise verify the results.

The teachers expressed that their outlook on AL and ALSs, as well as their motivation to continue their transition to the ALSs, was positively impacted by the sense of shared community they got from being a part of a team consisting of the researcher and the other teachers, the support they received from the researcher and the other teachers, and the opportunity to talk and discuss with their other teachers who went through a similar experience at the same time. Indeed, without any inference, it is not very likely that the teachers would have transitioned to the ALSs at this time.

2.3.4 The Teachers and their Teaching Methods

Of the four teachers who participated in the study, two had previous experience with using AL in the form of an SRS. However, none of them had any prior experience with using ALSs. The teachers taught two different statistics courses, one calculus course, and one numerical mathematics course (see Table 1 in Aga 2023a). All the four teachers were men.

All the teachers used SRS questions, one used mini-exercises, and another used exercise sessions. Typically, each 45-minute teaching session had two to three SRS questions. Each question lasted around 2-6 minutes. First, the teachers typically asked a question and gave the students some time to think and problem-solve individually before encouraging them to discuss their answers in groups. When the group discussion quieted down, and most students had answered, the teacher presented the solution. How deeply the teacher addressed the task depended on how well the students appeared to have understood the task, and whether there were any misunderstandings. The mini-exercises were composed of three to four questions, and students got approximately 15 minutes to complete them before the teachers presented the solution. An exercise session lasted the whole class time, 2x45 minutes. Here the students

worked on a longer task divided into smaller subtasks. The teacher delivered an introduction, then an explanation of the subtasks, and finally, a task summary. Throughout the sessions, the teacher was also available for any questions.

2.3.5 The Students

Almost all of the students had a Norwegian educational background. The students came from many different study programs, and some had previously attended other studies. However, the students had limited background in using AL and ALSs in higher education. There were a total of 481 registered students across the four courses. Of the four courses, there were two statistics courses, one for science students and one for engineering students. Furthermore, there was a calculus course for engineering students and a numerical mathematics course for STEM students. Among the students who took part in the focus-group interviews there was an approximately equal distribution of men and women.

2.4 Data Collection

This section presents briefly all the collected data relevant for the thesis. For a more detailed presentation of the data material see the individual papers presented later.

The research project planned to follow the teachers for two semesters, where each of the teachers would teach one course per semester. However, the second semester was only partially observed and mostly taught online in the spring of 2020 due to the Covid-pandemic. Thus, most of the data collected and the four courses referred to are from the first semester, i.e., the fall of 2019.

Each course typically consisted of two 2x45 minute class sessions per week throughout the semester. A semester typically had 13-14 weeks with teaching activities. In the rest of the text a *course* represents a unit of 7.5 or 10 ECTS, while a *class* or *class session* refers to a 2x45minute unit.

Classroom observations were used as a fundament to understand the teachers, the students, and the classroom environment. Furthermore, individual semi-structured interviews, group reflection conversations, and post-observation conversations were conducted to gather data on the teachers' perspectives on the ALSs and teaching in this context. Additionally, student data were gathered through a survey and focus group interviews. These data collection tools are described in more detail below, in Table 2.

Table 2. A summary of all the data material used in this thesis.

Data source	Data type	Group size	Frequency	Paper
Classroom observation (indirectly used)	Notes	The researcher + teacher and class	4-6 times per teacher	Used for understanding the context better
Individual semi-structured interviews with teachers	Audio (transcribed)	The researcher + one teacher	One pre-interview per teacher One post-interview per teacher One post-project interview per teacher	Papers I and III
Group reflection conversation with teachers	Audio (transcribed)	The researcher + 2-4 teachers	Five times – varying composition of teachers	Papers I and III
Post-observation conversation with teachers	Audio (transcribed)	The researcher + one teacher	1-2 times per teacher	Papers I and III
Student survey	Written	Courses surveyed: 4 Total responses: 181	One survey per course	Papers II and III
Semi-structured focus group interview of students	Audio (transcribed)	The researcher + group of mostly 3-4 students. Number of groups: 12 Number of students: 29	One interview per group of students – lasting roughly 2 hours per group.	Papers II and III

Classroom observations were conducted to understand the teaching strategies and the teaching environment better. While not directly contributing to the analysis, these observations served as valuable conversation starters with the teachers. The observations also aligned the researcher's understanding with the students' perspectives of the classroom environment and teaching practices. A total of 4-6 observations were conducted per course. These observations enriched the dialogue during interviews with teachers and students and guided the researcher in asking insightful questions and designing the survey.

Individual semi-structured interviews were one-to-one interviews used to understand the individual teacher's views on the value and challenges of using ALSs. It was initially designed for each teacher to be interviewed two times, once before they started teaching in the ALSs (pre-interview) and once after their first semester of teaching in the ALSs (post-interview). These interviews helped to identify the initial challenges teachers anticipated with the transition

to ALSs and how their views evolved after using the ALSs. In addition, in 2023, one interview was conducted on the teachers' reflections on ALSs relation specifically to mathematics and statistics (post-project interview) to help clarify and strengthen the data material for the third paper.

Group reflection conversations were regular physical conversations to which all the teachers were invited simultaneously. Most of the four teachers attended most meetings, but some were conducted with three or even only two teachers present. These conversations facilitated for the teachers to share and discuss their successful and challenging experiences from the ALSs with each other, and the researcher. Moreover, the researcher following the IAR approach (Postholm, 2007), guided these discussions (when necessary) and presented reading materials and teaching strategies when asked by the teachers to do so.

Post-observation conversations were held shortly after some of the classroom observations. In these conversations, the teachers were offered an opportunity to discuss their classroom performance with the researcher shortly after being observed. The researcher and the teachers then discussed their challenges during the specific class. These discussions helped the researcher compare his observational reflections with the teachers' direct classroom experience.

An open-ended survey was administered to all the students before the student interviews took place. This survey guided the researcher's focus for the interviews with the students where the answers in the survey were vague or unclear, and the interviews were used to clarify such uncertainties. The survey questions can be found in Table 4 in the supplementary materials in Paper II.

Semi-structured focus group interviews were the primary source of the student data used for this thesis. A total of 29 students were interviewed across 12 interview sessions from the four courses. Each interview, typically involving 3-4 students, lasted about two hours each or until the students had nothing more to share. The interviews provided insights into the students' self-reported experiences and perceptions of their AL and ALSs classes. The researcher used a guide but encouraged students to openly express their thoughts and feelings about AL, ALSs, and feelings and thoughts related to using such teaching strategies and spaces. The researcher encouraged the students to elaborate in-depth and asked for clarification when needed. Moreover, the researcher made efforts to create a safe and comfortable environment for

students to freely share positive and negative experiences and thoughts related to ALSs. It was highlighted that the students would be anonymized, and some time was spent in the beginning of each meeting to get to know the students, and make sure that the students also would get to know each other.

The collection of one data type often influenced the data collected through another method. For example, the classroom observations informed the interviews with the teachers and the students, and the student survey informed the interviews with the students. Moreover, the examples and experiences gained from the classroom observations were occasionally used as discussion points in the reflection conversations, and insights from the reflection conversations made the researcher pay special attention to certain elements during the next classroom observations. Additionally, the researcher's interactions with the teachers shaped their teaching practices and generated new discussion topics. Thus, all the data were collected as part of an iterative reflective process where the reflections associated with the data collection process influenced the data collection itself. In addition, the researcher also strived to make the whole research period and data collection process as safe and comfortable for the teachers as possible, allowing them to share their positive and negative experiences freely.

2.5 Data Analysis

The data analysis is described in detail in each of the respective papers. The constant comparative method was used as a part of grounded theory (Strauss & Corbin, 1998) to find underlying structures in the transcribed data material. This entailed analyzing the data through an iterative process, where each line of text was first labeled based on its topic. The text was repeatedly read and analyzed to refine these labels. Similar topics were eventually grouped into focused codes, which were then grouped into categories. The categories, focused codes, or content from such an analysis have been presented in their respective papers.

3 Results and Discussion

All three papers have grown out of the same research project. The data for the papers were collected concurrently through the phase where the four teachers transitioned to the ALSs. While following the teachers and their experiences with transitioning to the ALSs, data were also collected on the students' perspectives on their experiences in these classes.

The relation between the papers and their themes has been illustrated in Figure 2, which highlights that the core of the thesis is the teachers' and the students' experiences with AL and ALSs in general, and with mathematics or statistics in particular. The studies are designed primarily around interview data with teachers transitioning to ALSs and students attending these teachers' classes. While each of the papers has its specific perspective used to examine the ALSs, they are also related to each other, as illustrated in Figure 2.

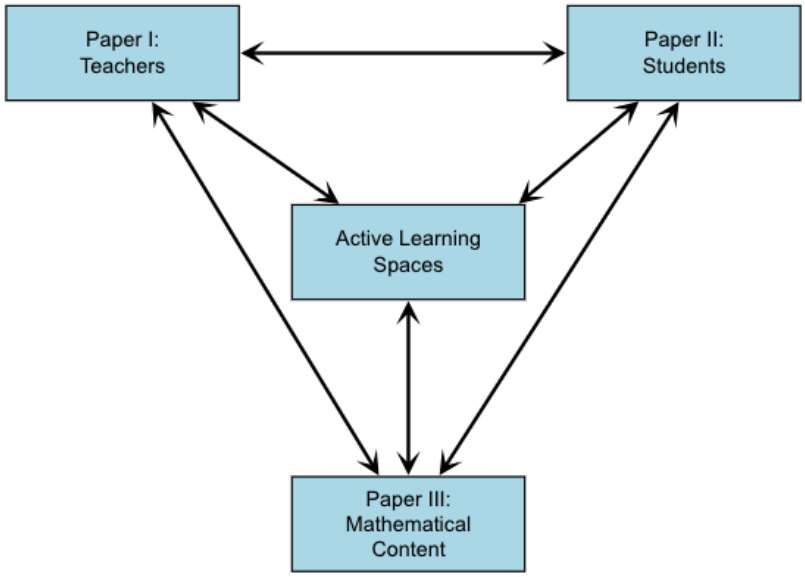

Figure 2. A visualization of the three papers, and how they are related to each other and the theme of Active Learning Spaces.

Figure 2 also illustrates the relations between the three papers, and the relations between the teachers, the students, and the mathematical content[2] in the ALS. The relations are

[2] In this thesis *mathematical content* refers to both statistical and mathematical content.

characterized by the qualities of the teacher-student interaction, by the relation of teachers and students to the ALS, by the relation between the ALS and the mathematical content, and finally by the relation between teacher, student, and the mathematical content to be learnt in the ALS. By excluding the ALSs, the remaining parts of Figure 2, i.e., the relations between the students, the teacher, and the mathematical content create what is usually referred to as the didactic triangle (Goodchild & Sriraman, 2012).

In Paper I, the teachers reflect on the students' behavior, and in Paper II, the students reflect on the teachers' behavior. In Paper I, some reflections are specifically related to mathematics or statistics, while in Paper III, many of the reflections are concerned with how the teachers handle the challenges specific to mathematics or statistics. Papers II and III are connected as some students communicated that they had negative emotions toward mathematics or statistics, which impacted how they related to AL and ALS.

Paper I is strongly concerned with teachers' reflections on the ALSs and their reflections on the students and teaching strategy in this context. Paper II is concerned with students' experiences in the ALSs. Finally, Paper III looks at the subject specific concerns of students and teachers in the ALSs. The content of the papers is further presented in the next section, which summarizes the papers. The results are discussed in Section 3.2.

3.1 Summary of Papers

3.1.1 Summary of Paper I

Paper I addresses three research questions:

1) What do the teachers perceive to be significant challenges to overcome when transitioning to ALSs?
2) What did the teachers do to overcome the challenges?
3) How do the teachers perceive that their motivation and their challenges mutually affect each other?

Research question one resulted in the identification of three categories describing what the teachers perceived to be significant challenges to overcome, when transitioning to ALSs. The categories are *Engaging Students*, *Building Student Relations*, and *Developing Teaching Strategies*. Once identified, the categories were examined for answers to research questions two and three, what the teachers did to overcome the challenges, and how these challenges impacted their motivation.

In summary, the transition to ALSs demanded that the teachers, to a greater degree, became aware of many of the social aspects and challenges in these spaces, such as engaging the students. The teachers had to focus more on what they themselves had to do to overcome the newfound challenges as they employed strategies such as explaining the purpose behind the activities for the students. While there were many good motivational aspects about transitioning to the ALSs, there were also motivational challenges. The transition was understood to demand more time, and there was a worry about what teacher peers would think about them as teachers if they were to fail in their transition to the ALSs. Overall, the teachers reflected that many of the challenges would be easier to overcome with professional development support.

Finally, the teachers perceived that it was not necessary to master the transition perfectly but that it was essential to handle the challenges proficiently to benefit from the ALSs. Moreover, it was noted that while skillful handling of one challenge could make it easier to handle the other categories, poor handling of one category could also make handling the others more difficult.

3.1.2 Summary of Paper II

The second paper addresses what factors students perceive necessary for a good ALS experience. The answer to the research question is characterized by one single main category named Engagement and Comfort, with three-subcategories named *Students' Varying Preferences*, *Student-Student Communication*, and *Teachers' Communication*.

It was especially noteworthy that some students experienced it so uncomfortable to participate during the AL segments in the ALSs that it either reduced their learning outcomes, made them not participate during class, or even avoided coming to class. Thus, to have students benefit from the ALSs, it is crucial that they are comfortable enough to show up and engage. Elements that improve students' comfort in the sense that they are more likely to engage in the ALSs are presented in all sub-categories. Clearly, good student-student communication facilitated by good group dynamics and teacher communication present additional aspects that influence students' perception of the value of ALSs.

The students reported varying preferences that were often contrasting with each other, i.e., some students wanted more AL elements and others wanted less, while some students wanted to be seated with friends and others randomly. Therefore, it was challenging for the teachers to accommodate all the students' preferences simultaneously. Many of the students' preferences appeared based on what they found comfortable or uncomfortable. It is therefore

conjectured that working toward making the students comfortable in the ALS setting is an important measure to get them to appreciate these classes and make them engage and benefit from them.

The students' reflections presented in Paper II should be helpful for professional development of the teachers transitioning to ALSs and be used to inform teachers about students' perceptions in ways that can help them communicate better with their students and thereby improving the learning outcomes in ALSs.

3.1.3 Summary of Paper III

The third paper addresses teachers' challenges in using ALSs, specifically in the context of mathematics and statistics. For this paper, one main category with four sub-categories was identified. The main category was named *Teachers' Challenges*. The four sub-categories were named *Finding Suitable Tasks*, *Covering the Material*, *the Nature of Mathematics*, and *Students' Emotions*.

Pertaining to the first sub-category, *Finding Suitable Tasks*, it was reflected that in mathematics and statistics, conceptual and contextual tasks worked better to engage students than more procedural tasks, especially in the ALS context.

In the second sub-category, *Covering the Material*, it is noted that while the teachers were happy with using AL and ALSs, they felt a responsibility to cover the full curriculum during class, especially since mathematics and statistics was considered to build more on previous knowledge than other subjects. Lecturing was considered to be the most efficient way to cover the curriculum, resulting in a significant portion of the ALS classes being used for lecturing, rather than active learning activities.

The third sub-category, *the Nature of Mathematics*, describes that the teachers felt that it was particularly hard to make good ALS classes in mathematics and statistics, as mathematics and statistics to a high degree is built strongly on previous knowledge. The teachers found it hard to design tasks that fit student groups with varying background knowledge. That mathematics and statistics is also quite abstract, was felt to make it harder to make good contextual tasks.

Finally, the sub-category *Students' Emotions* characterizes that not all of the students liked working with mathematics or statistics, and that strong negative feelings about mathematics or statistics in particular may make it more difficult to engage students in these classes, making AL and ALS use more challenging. Indeed, some students indicated that they

participated little in these classes, partly because of negative emotions related to mathematics or statistics.

Overall, even the subject specific concerns of teachers were related to engaging students in the AL and ALSs. More importantly, while the teachers found that it may be harder to engage and facilitate discussions in mathematics or statistics than in other subjects, they still felt it to be meaningful to employ strategies to engage the students. Such strategies could both be specific to the subject and activity or general to all learning activities and subjects.

3.2 Reflections on the Main Results

How was the relation between engagement and good ALS use perceived?

A central theme across the papers was the students' engagement in the ALSs and how this related to good ALS classes. In Paper I, the first category**,** *Engaging Students***,** addressed the teachers' reflections on what was challenging and essential about engaging the students. The other two categories presented in Paper I, *Building Student Relations* and *Developing Teaching Strategies,* were felt to be vital as they could support the teachers in overcoming the challenge to engage the students. In Paper II, the students' reflections revealed that it was essential to facilitate for the students to be comfortable in order for them to engage with the learning activities in the ALSs. In Paper III, it was discussed how the design of different mathematical and statistical tasks could work to better engage the students.

Some of the important relations between the papers, as illustrated in Figure 2, can be characterized as follows. The relation between Papers I and II is in part characterized by the teachers' experience that the students engaged too little, what the teachers felt the students could do to engage and what they felt that they could do to support the students to engage (Aga 2023a), but also what the students felt that the teachers could do (Aga, 2023b). The relation between Paper I (teacher challenges) and III (subject specific challenges) is characterized by that the teachers felt that mathematics and statistics is more difficult overall in ALSs, increasing the challenge of transitioning. Finally, the relation between Papers II and III is that some students had negative emotions specifically towards mathematics or statistics, making them struggle with engagement in the learning activities.

Regardless of what point of view one uses to examine the papers and the challenges related to using and transitioning the ALSs, at the core of this thesis is teachers' transition to ALSs. In this transition, the teachers reflected that when their teaching space was changed, they

also had to change their teaching practice. However, as has been reported elsewhere teachers need to believe in these strategies to effectively teach using AL methods (Lasry et al., 2014).

Traditionally, teaching has been seen as a one-way process, with teachers imparting knowledge and students passively receiving it (Dennick, 2016). The ALSs were felt to necessitate a more interactive and participatory approach to teaching, where the students' learning, actively and interactively, was at the core. Thus, a consequence of transitioning to the ALSs was a change in teaching practices, which in turn necessitated a change in outlook on teaching strategies. The teachers increasingly reflected that it was necessary for the students to actively be a part of the learning processes. However, the teachers also quickly experienced that it was challenging to engage the students as much as they had intended. Thus, working toward engaging the students quickly became a core challenge that had to be overcome for the students to benefit from the ALSs.

Like the teachers, the students generally felt that it was more beneficial for their learning outcomes if they engaged in the activities in the class. Additionally, the students also felt, in agreement with Brooks (2011), that the ALSs made it more natural and expected for them to participate in the activities, and that the affordances of the ALSs, particularly the easier access to peers at the group tables, made it easier to be engaged in interaction.

However, not all students engaged in the activities in the ALSs. Some students reported that they rather wanted to sit back, relax, and listen to the teacher's lecture. Students who chose not to engage in the ALSs challenged the teachers as the teachers had to develop their skills in order to engage the students better. While the teachers had no simple answer to what a good use of ALSs looked like, they all agreed that it necessitated that the students engaged with the teaching activities in these spaces.

How was the relation between engagement and motivation in the ALSs perceived?

In Papers I and II, the teachers' and the students' opinions reflect that it was challenging to transition to the ALSs, as the change in space also came with a change in teaching strategy, as noted above. Furthermore, for this teaching strategy to be successful, it was necessary to think differently about both teachers' and students' roles in the ALS. It appears that teachers and students alike were only partially ready for this shift in pedagogy and space. Many of the teachers and students reported benefiting from and liking this shift in learning space, while some reported to prefer not using ALSs. Among those who preferred the ALSs, both teachers and students, there were many reflections on how the use of such spaces could improve.

Paper II reports that most of the students who chose not to engage, or only partially engage in the ALSs, did so because they found some element associated with such engagement uncomfortable. Indeed, engagement was associated with something positive and negative for many students. The positive aspects of engaging in the ALSs were that most students expressed that they perceived it beneficial for themselves and their learning to engage in the ALSs. However, several of these students also expressed that they felt a need to avoid engaging for various reasons, often due to social discomfort. Thus, from this perspective, two straightforward approaches exist to increase students' motivation to engage in ALSs. Firstly, one can increase the positive aspects, i.e., increase how beneficial the students view engagement in the ALSs, and secondly, one can reduce the negative aspects related to engagement in the ALSs.

It is interesting to note that despite previous reports that students may resist participating in AL (Andrews et al., 2020; Deslauriers et al., 2019), Paper II highlights that students mainly resisted engaging in the ALSs due to the discomfort that engagement with AL is perceived to entail. That discomfort was what discouraged students from engaging in the ALSs should be used to inform and support teachers to adapt their engagement strategies to their students' needs. Teachers should also be encouraged to establish effective communication strategies to connect with their students and to collect information on obstacles that may be specific to the student group at hand. In brief, a better understanding of students may likely lead to improved use of already suggested strategies for reducing student resistance (Aga 2023a, Finelli et al., 2018; Tharayil et al., 2018).

The teachers' own motivation to transition also mattered. Paper I presents how the teachers' motivation impacts the teachers' effort, commitment, knowledge, and teaching strategy when transitioning to the ALSs. In brief, the more meaningful the teachers felt it to be to transition to the ALSs, the more resources and time the teachers were willing to invest into this transition. However, the results show that it was also important that the teachers had realistic expectations about the difficulty of transitioning and were informed by peers, professional development programs, or other support systems to work toward the transition in a meaningful way.

What makes engaging the students difficult can also be understood as a challenge in going from a traditional pedagogical view to a more student active pedagogical view. Beliefs related to traditional pedagogical views are that the teacher is at the center of the classroom while the student takes the role of a listener, while in the student active pedagogical view the student needs to be active and at the center of the learning activity.

In this thesis, such tension between these two pedagogical views is reflected in that teachers may have only a partially student-centered view on teaching (Aga, 2023a, 2023c), teachers try to engage the students while students partially resist (Aga 2023a, 2023b), students want behavior that better fits with the ALSs both from teachers, peers, and themselves (Aga, 2023b), and the tension between designing suitably challenging tasks for the students to work on that are either easy to design (procedural tasks) or better for engagement (conceptual and contextual tasks) (Aga, 2023c).

This shift in pedagogical views also necessitates that the teachers' and students' motivation shifts to fit the new pedagogical views. It is discussed in Papers I and III that while the teachers believed that AL and ALSs could improve their teaching, they did not necessarily have an outlook on the teaching where the students stood at the center (Kugel, 1993). Indeed, the teachers in this research project may be in the process of changing their pedagogical views, as is in part reflected by that the teachers felt it was essential to cover the curriculum with lecturing at the cost of more active pedagogies.

The teachers' choice of teaching strategies is further explored in Paper I, which discusses how most teachers chose an active learning enhanced lecture over a more actively focused teaching strategy. Such a teaching strategy preference may reflect that the teachers' teaching philosophy is situated between the traditional view and the student-centered view.

Some teachers expressed that they feared the poor perceptions from their peers could have negative consequences. It is worth considering that perhaps even teachers who are self-motivated enough to willingly transition to ALSs and have a view of the students as active learners are still so used to traditional teaching methods that they are not prepared to make the complete transition to new teaching strategies.

Indeed, the teachers reported that they feared that if they challenged the traditional view, which was felt that many of their colleagues still had, they would risk being criticized if they received poor student learning outcomes. However, it was not felt that they risked the same poor perceptions from peers if they would get poor student learning outcomes using traditional teaching methods. Thus, at least some of the teachers' fear of poor perception appears not rooted in students' learning outcomes but rather based on a fear of challenging the traditional pedagogical teaching culture.

3.3 Possibilities for Future Research

While knowledge about learning spaces and in particular ALSs is increasing, there is still room for improving the theoretical understanding of such learning spaces and the value they can add to learning situations. Anecdotal evidence suggests that one common misconception of ALS users is that such spaces can single-handedly improve educational quality. However, a core reflection is that any learning space, including ALSs, is highly dependent on teaching strategy and context to support improved student learning outcomes. At the same time, other academic staff may not be open to the possibility of how ALSs can improve education. Regardless of stance, there is a risk of misunderstanding the potential benefit of different learning spaces. Indeed, throughout talking to academic staff about learning spaces, many clear misconceptions have presented themselves, such as that there is one best type of learning space, that learning spaces do not impact the quality of learning, that lecturing in ALSs is inherently better than lecturing in lecture halls, and that there are no downsides to ALS use.

The debate on ALSs can be polarizing if ALSs are seen as either highly beneficial or detrimental. Assessing the spaces in the context in which they are used could reduce the polarization of views and clear up misconceptions.

The reflections presented below in Sections 3.3.1 and 3.3.2 suggest a beneficial way for researchers, teachers, and professional development staff to view and examine the use of different learning spaces. Particularly, it may support teachers interested in transitioning to make use of ALSs by removing some common pitfalls in using learning spaces, cf. Section 3.4.2.

3.3.1 Four Fundamental Reflections

Based on the literature review and reflections on learning spaces throughout the research project, four fundamental reflections about the role of learning spaces arose. While these reflections may at times seem basic or self-evident, they are the result of the researcher's reflections on the observation that both stakeholders and users of these spaces often make basic mistakes that could be addressed by reflecting on the fundamental character of such spaces and adjusting actions accordingly.

The key takeaway from these four reflections is that the value of all learning spaces depends on the context in which they are used. This context-dependent outlook resonates with the Interaction Equivalency Theorem (IET), which states that there is no best teaching-learning

method, and that high-quality student-student interaction can be replaced by high-quality student-teacher or student-content interaction (Miyazoe & Andersson, 2010).

The idea that there is no perfect learning space for every situation has been broken down into four fundamental reflections that may illuminate how learning spaces can add value in different contexts.

The four fundamental reflections are:

A. All spaces can facilitate learning.
B. Different spaces are conducive to different learning activities, as the affordances of the spaces can be positive or negative depending on the context.
C. Some characteristics of spaces can be positive or negative, regardless of context.
D. There is no single best learning space. A good space is a space that fits the needs and wants of the students and teachers.

A. All spaces can facilitate learning

For a learning space to facilitate learning, it needs to add something of value to the learning process or allow particular action in the space. Any space that facilitates sensory input can be conducive to learning in a given context. For example, if it is possible to see and talk to other people in a space, the space can facilitate learning through talking and movement. While it is theoretically possible to think of a space that lends no qualities that can facilitate learning, this is of no real practical concern, so it is here suggested that all spaces can (to some degree) facilitate learning. However, not all spaces are conducive to *high-quality* learning (Bennet, 2011; Vandiver, 2011). For example, a space where one can talk but the acoustic quality is poor is not conducive to high-quality learning, and risks excluding some students from the learning activity. This will be further reflected on in the following points.

B. Different spaces are conducive to different learning activities, as the affordances of the spaces can be positive or negative depending on the context.

That the effectiveness of a learning space depends on the activity conducted in it is partially argued for in the previous point but is further explored here. While ALSs are likely to enhance learning outcomes when used with AL (Baepler et al., 2016; Brooks & Solheim, 2014), such spaces may reduce learning outcomes when used for lecturing, at least compared to spaces designed for lecturing purposes (Aga 2023b). For example,

ALSs may not be ideal for lectures because they are designed for interaction, leading to possible non-academic discussions.

This view is supported by various studies that have confirmed that the effectiveness of learning spaces varies depending on the learning activities conducted within them (Brooks & Solheim, 2014; Fox et al., 2012). Typically, the design of learning spaces is aligned with the goal of the learning activity that is expected to occur in them (Bennet, 2007). However, this does not guarantee that the spaces will be used as intended. It is therefore highly desirable to understand the relation between an activity and the assigned or chosen space to leverage the learning space effectively.

C. Some characteristics of spaces can be positive or negative, regardless of context.

While most features of learning spaces can be beneficial or detrimental depending on the context, some elements, such as light, acoustics, air quality, temperature, and comfort, may be considered universal in their impact on learning opportunities. These essential characteristics, which support sensory input and basic human comfort, must be of high quality for a learning space to be effective.

For instance, reduced physical and social distance between students and teachers can facilitate teacher-student interactions, positively impacting students' learning outcomes (Bogardus, 1928; Cole, 1999; Hazari, 2015; Waller, 1932). However, for teachers or students with varying degrees of social anxiety, a space that encourages such interaction may cause discomfort, potentially reducing learning quality (Aga 2023a).

Teachers and students have often requested better quality with respect to air, light, acoustics, and comfort (Pedro, 2017). Indeed, high levels of CO_2 in classrooms have been confirmed to significantly impair students' cognitive functions (Coley et al., 2017). It is worth noting that a typical classroom has about one tenth of the floor space per person compared to a typical office (Crawford, 1998). Thus, one should not apply the same designs for classrooms as one would for an office, nor should one apply the same design for all learning spaces.

D. There is no single best learning space. A good space is a space that fits the needs and wants of the students and teachers.

As stated in the previous points, the quality of learning spaces is contingent upon the context in which they are used, implying that no single learning space can be deemed

the best for all situations. A space may be beneficial for one purpose and detrimental for another. The quality of a learning space depends on the purpose and needs of the people using it. A good space is a space that is aligned with the needs and wants of its users.

As already discussed, ALSs, or spaces designed for student interaction, are likely to improve student learning outcomes when paired with AL and less likely to improve it when paired with lecturing (Aga 2023a, 2023b; Brooks & Solheim, 2014).

3.3.2 A Model of the Value of Learning Spaces

Based on the literature review, observations during the research project, and as an extension of the reflections presented in the previous section, a model for the value of learning spaces is suggested here. The model is not limited to use in ALSs and should be applicable to any space where learning activities take place, regardless of learning activity and of spatial design.

Building on the idea that a good learning space is a space that fits the needs and wants of its users, the quality of a learning space needs to be assessed within the context in which it is used. The primary stakeholders in creating this context are the teacher and the students.

The purpose here is limited to address the elements most closely related to the space, to provide a starting point for discussion, and to propose a lens for discussing the value of learning spaces and their interactions with teachers, students, and learning activities. While the suggested model could be made more comprehensive by including other elements that may impact the value of the learning space, such as the particular subject matter, the educational culture at the institution as well as content resources, such as books and AI-language tools, these have been ignored for the sake of simplicity.

In brief, it is suggested that the quality of learning in a space can be understood through two groups, each consisting of three components. The first group of three consists of the *independent value components*, i.e., the independent quality of the learning space, the independent quality of the teacher(s), and the independent quality of the students. The second group of three elements consists of the *interaction components* teacher–learning space interaction, student–teacher interaction, and student–learning space interaction. In the simplest application, each of these components can be assessed to be of low, medium, or high quality.

Taking the three independent value components and the three interaction components into consideration a hexagonal diagram (the grey area in Figure 3) consisting of six (red) axes can be constructed. An assessed value of low, medium, or high quality can be assigned to each of the six axes to indicate the quality of each of the six components. By drawing a line between

the neighboring assessed values along the axes a new hexagon (the green area) is created. This area visualizes the realized effect on learning for a specific combination of teacher, students, and learning space. Additionally, this area gives an impression of what can or should be further developed. The model is clearly qualitative and offers a quick and useful heuristic for basing choices related to teaching with an emphasis on using the learning space in a good way, and for comparing different combinations of teachers, students, and spaces with possibilities for discussing trade-offs, and what modes of learning activity may be more efficient.

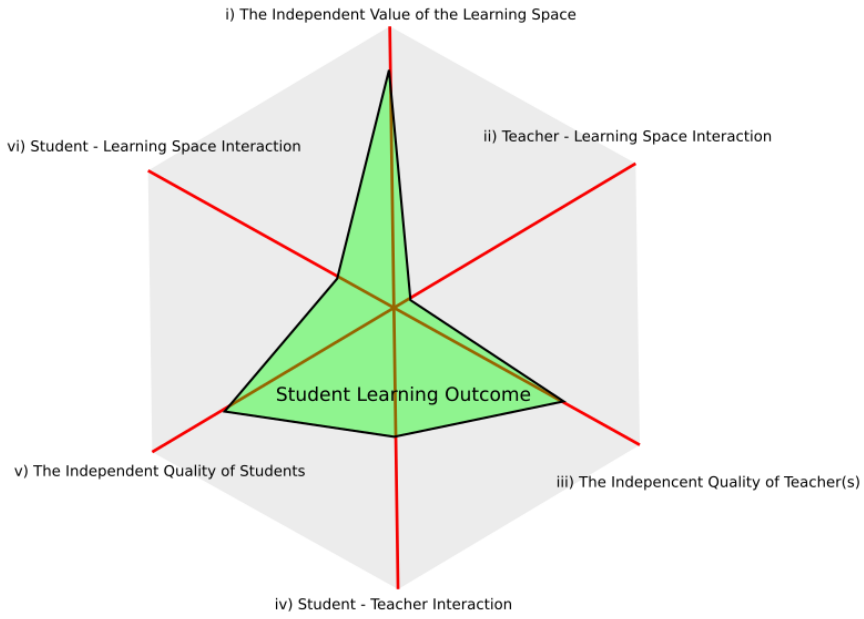

Figure 3. A model suggesting how the components can be used to assess the quality of a learning space in context. This example is of a scenario where the learning space has excellent value on its own, and the teacher and students have generally good behavior. Furthermore, the students and teacher interact reasonably well, but the students use the room poorly, and the teacher uses the room exceptionally poorly.

The model is simple and potentially useful but does have clear limitations for comparing different situations if too many of the six components arise from different settings. Note that the subject is not a part of the model, but implicitly included in the components. For example, teacher-student interaction can be related to how well the teacher communicates how to address mathematical or statistical challenges.

Moreover, it is worth noticing that only three elements are directly concerned with the learning space: elements i), ii), and vi) (see Figure 3). However, other elements are included, for example, iv) student-teacher interaction may influence the quality of the learning space if the teacher is to, for example, encourage the students to use the space in a certain way. Of further note is that these reflections do not stipulate how to measure the quality of each of the six components; rather, the model suggests a way to find the weaknesses and strengths in the learning context. The model is not intended to be used as an evaluation tool to grade successful use of learning spaces, rather it is meant to support improved use of learning spaces by encouraging reflections on potential shortcomings in one's use of learning spaces.

Reflections on the Independent Value Components

The independent value components concern the capabilities of the teacher, student, and learning space as seen independent of context. As stated earlier, the model does not prescribe how to assess the quality of the components. Common for all independent value components is that they could be assessed through factors that can be evaluated regardless of context. For example, *the independent value of the learning space* can be assessed through characteristics such as those mentioned in principle C), such as air quality, lighting, sound quality, and sufficient space for the students are essential to assess this value.

Moreover, *the independent quality of the teacher(s)* can be assessed through some behavior or skills of the teachers. For example, the teacher's knowledge of the course material, and understanding of difficulties students may experience in learning the course material.

Furthermore**,** *the independent quality of students* can be assessed through the student's motivation, earlier knowledge, and problem-solving strategies.

Reflections on the Interaction Components

The *interaction components* are concerned with how well the different independent value components work together or interact. Like the independent value components, it is not prescribed how to assess these components. The purpose of the interaction components is to stress the importance of how the different main components work together, reflecting that the value of ALSs is context dependent.

An example of good *teacher-student interaction* is that the teacher successfully encourages the students to interact and ask relevant questions to the teacher. Teachers showing warmth and friendliness are correlated with positive student learning outcomes (Tharayil et al., 2018; Vandenbroucke et al., 2018). It is also necessary that students are enthusiastic, respectful,

and interested in the subject matter, as teachers report that this makes it more worthwhile to teach and spend resources on quality teaching (Aga 2023a).

The component for *the teacher-learning space interaction* represents how well the teaching fits the learning space. Good teacher-learning space interaction requires that the teacher's chosen pedagogy for the class matches the affordances of the room.

Finally, *the Student-learning space interaction* represents how well the students interact with the learning space. Good student-learning space interaction is characterized by students that are aware of the affordances that the space offers and how to use these affordances constructively. For instance, if the students learn better from group work and the learning space has group tables, good student-learning space interaction demands that students choose to work with peers and pursue constructive interaction.

Further Reflections on the Model

The above fundamental reflections and the model on the value of learning spaces are meant to stress how valuable it is that teachers, students, and learning spaces interact productively with each other. For high-value learning space experiences, it is necessary to consider more than just the learning space itself. Hopefully, the results and reflections presented here can contribute to inspire discussions on student behavior, teaching skills, learning space, and learning space design and how these components come together. Moreover, while the suggested model is simple it should be useful for improving theoretical understanding of the value of learning spaces, as well as be useful as a tool to support teachers and other stakeholders in analyzing the relation between learning activity and space.

The reflections and model presented here can still be further built upon. Listed below are five potential avenues for future development:

i) Defining more precisely what each of the components in the model entails.
ii) Including more components (with the risk of complicating the model and making it harder to interpret).
iii) Developing more precise instructions on how to assess the value of each component.
iv) Reflecting further on how the area of the green hexagon in the model relates to improved learning or better used learning spaces.
v) Elucidating each component and breaking it up into finer components for a more nuanced understanding.

Yet, the model's immediate purpose is to support teachers and other users of learning spaces in using these spaces well. While expanding the model and the reflections may provide a more nuanced and detailed theoretical understanding, it may also make it less likely that teachers use it as it becomes more difficult to familiarize themselves with the model and the reflections.

3.3.3 Additional Avenues for Future Studies

In Sections 3.3.1 and 3.3.2, theoretical possibilities for future research were explored. In this section it is explored how elements in the papers can be further built upon for further studies.

General suggestions for all the papers are that they can be built upon and further explored through the impact of different contexts, for example, by setting up a similar study in a different subject. Also, studies within the same context could be designed to confirm the consistency of the results. The study design could be changed to explore the long-term effects and impacts of teachers who have transitioned to ALSs. Furthermore, quantitative studies could be designed to verify the impact of the results and reduce the subjectivity of the findings. Finally, the findings from the papers could be used to make changes to the educational situation, and in turn, the impact of these changes could be measured.

The last point is particularly interesting for its more direct potential impact on improving conditions for student learning outcomes and other aspects of the educational context. The findings could be used to improve the quality of learning activities by using the results across the papers to develop professional development program(s) for teachers transitioning to the ALSs, and asses the effectiveness of such programs.

The findings from Paper I could be used to highlight the importance of aspects such as student engagement, building student relations, and developing teaching strategies to different degrees. The findings from Paper II could be used to inform teachers on how students experience the use of ALSs and encourage teachers to consider what it takes to make students more comfortable in the ALS setting. Paper III might also inform professional development, but it would make sense to first study the effect of different task designs in mathematics or statistics in an ALS. For example, one cohort may be taught with more procedural and non-contextual tasks, while another cohort is taught with more conceptual and contextual tasks. The results of such a study should be informed not only by measuring student learning outcomes but also student engagement, student and teacher satisfaction, and other similar metrics.

3.4 Implications of the Research

As stated in Section 3.3.3, the implications and potential for this research to improve the quality of learning activities are largely through informing professional development, which in turn can inform and support teachers on how to transition to ALSs, engage the students, and design appropriate mathematical or statistical tasks that work well to engage students in the ALSs. In addition, the findings can be used to inform institutional change and further changes that support teachers and students in using ALSs well. Additionally, the model in Section 3.3.2 can also be used as a problem-solving tool to find and avoid common pitfalls related to ALS use.

3.4.1 How can the findings be used to engage the students better?

All three papers address, to some extent, how to better engage students in the ALSs by identifying existing challenges, both actual and perceived. In Paper I it was found that the teachers' reflections identified that building good relations with the students and designing a teaching strategy to activate and engage the students in the ALSs are essential. The strategies presented and discussed in Paper I have many similarities with other strategies suggested in the literature, confirming their potential positive impact (Finelli et al., 2018; Tharayil et al., 2018).

Paper II reports a significant variation among the students' reflections on their preferences with respect to different aspects of learning activities and group dynamics. However, the students' preferences on how teachers could communicate to support the students engagement were more consistent. Overall, the students gave more weight to the importance of teachers clarifying expectations and creating an environment that made it comfortable to engage in the ALSs. In general, the students' insights, preferences, and reported needs can be used to inform the teachers on the students' needs in order to better support engagement in the ALSs. Such reflections by the students are aligned with already suggested strategies and may well further improve the impact of them (Finelli et al., 2018; Tharayil et al., 2018).

Paper III discusses the challenges of creating suitable tasks for the students to work with in the ALSs and presents how the teachers reflected that they were used to creating procedural tasks, which worked poorly to engage the students through discussion. However, the teachers experienced that tasks that were conceptual, contextual, or both conceptual and contextual worked much better at creating a discussion, even across different student proficiency levels. The findings from Paper III can therefore be used to inspire teachers to design a greater number of conceptual and contextual tasks to better engage the students.

The various challenges presented in all three papers highlight the need for comprehensive support systems to help teachers navigate the transition to ALSs. Such support systems could leverage the findings from the papers in this thesis to inform professional development programs particularly with respect to strategies for engaging students and overcoming student resistance, such as building student relationships, and developing effective teaching strategies for ALSs.

A part of any professional development program should underscore the importance of creating a supportive and safe environment where teachers can share their experiences, challenges, and successes with peers. Also, the institutional culture should be addressed to increase teachers' motivation and comfort in engaging in discussions on ALSs. Elements that could support such cultural changes are facilitated peer observations of teaching sessions, group reflections conversations, and post-observation discussions with both peers and professional development staff.

3.4.2 Potential Pitfalls in ALS Use

By using the model presented in 3.3.2, some common pitfalls in using ALSs are examined here. Identifying such pitfalls can support better ALS use. The pitfalls discussed below are based on observations made throughout the work on this thesis.

1. **Low-quality interaction between teacher and learning space**

   Lecturing in ALSs: A suboptimal way to use the ALSs is with a lecturing style with only very few, if any, AL elements. Although ALSs have been linked to positive student learning outcomes, students have reported that they experience that using ALSs for pure lecturing classes makes their classes worse (Aga 2023b). When ALSs are used for pure lecturing, the space and pedagogy are not well aligned and are working toward opposite goals. The room encourages the students to interact, while the teacher does not facilitate interaction. The students report that this can be confusing and that it invites interactions that distract them from the lecture and impede their learning (Aga 2023b).

2. **Low-quality interaction between teacher and students**

   Not communicating clear goals: It has now been covered that ALSs should be paired with some form of AL elements. However, another potential suboptimal way to use the ALSs is when teachers intending to use AL in the ALSs, fail to communicate the purpose of their AL segments to their students. Particularly, students new to ALSs may misunderstand the

teacher's intention and resist engaging with the activities (Aga, 2023a, 2023b; Deslauriers et al., 2019). It is therefore important that the teachers clearly communicate the purpose of their chosen teaching strategy and stress how the strategy has been chosen to benefit the students. It should also be clearly communicated what the students need to do for the teaching strategy to succeed, and that they have a part of the responsibility for creating a good class. Other strategies that can be employed to engage the students and overcome their resistance to AL are explored in (Aga 2023a; Tharayil et al., 2018; Finelli et al., 2018). Finally, better understanding the students' needs in the ALSs can help (Aga 2023b) and designing mathematical or statistical tasks that encourage students' engagement (Aga, 2023c).

3. **Medium-quality interaction between teacher and student**

   To not practice what you preach: Even when teachers have accepted that they should combine AL use and ALSs and communicate teaching strategy purposes and expectations to the students, there is still a risk that teachers will implicitly communicate that it is okay to not participate during the AL segments. Indeed, students reflected that teachers' non-verbal communication mattered a lot, and it was much easier to interact and engage in a class where the teacher showed enthusiasm and engaged with the students (Aga, 2023b).

4. **Low-quality student and learning space interaction**

   Whiteboard and screen use by the students: In one ALS session, the student groups were pushed to use the whiteboard to work together. Right before the half-time break, the students answered the teaching assistant that they liked using the whiteboard and were glad they were pushed to use it. However, when they returned after the 15-minute break and continued the task, they stopped using the whiteboard as no direct instructions had been given to continue using the whiteboard.

   Of course, this particular observational anecdote can be taken as evidence that the teachers need to *repeatedly* underline the expectations for the students and increase the student comfort in the ALSs. However, this story also underlines that the students have a responsibility to take independent action and make choices that will benefit their learning, and as such has been categorized under poor interaction between the learning space and students.

To show how the model introduced in Section 3.3.2 and Figure 3 can be used to illustrate some of these pitfalls, see Figure 4. In the left-hand figure, the independent value components are of high quality, while the interactive components are severely lacking in quality. The right-hand figure shows the case where students, teachers and space are of medium quality, but the interactions are of very high quality. The size of the green area is considerably larger in the right-hand figure, providing food for thought about the relative influences on learning outcome – provided that the model is useful. The reader is encouraged to create diagrams for case 1-4 above and ponder the relative characteristics of what the corresponding model figures would look like.

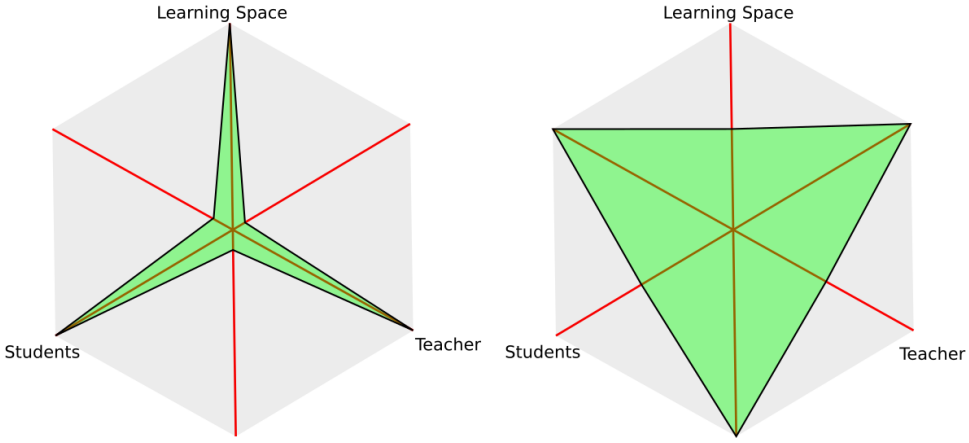

Figure 4. Two more examples of using the model presented in Section 3.3.2 and Figure 3. In the first example, the teacher, learning space, and students have excellent qualities, but the students and teachers interact poorly with the space and each other. In the second example, the teacher, learning space, and students have medium qualities but interact excellently with each other. Therefore, the model stresses the importance of avoiding the pitfalls explored in Section 3.4.2

3.5 Conclusion and Summary

This section discusses some of the limitations of the study, the conclusion, and a summary of the thesis.

3.5.1 Limitations

The three papers relied on interview data, which are subject to many types of subjectivity and bias, such as the subjectivity of each of the interviewed persons. Such subjectivity was partly addressed through interviewing several people. However, all the people may be subject to similar subjective thinking due to the cultural context.

Social desirability bias is bias in the form of interviewees being inclined to provide responses they perceive as socially acceptable or desirable rather than expressing their true beliefs. A measure implemented to reduce such bias was repeatedly stressing to teachers and students that the interview data would be anonymized and have no impact on them based on the reflections shared. Recall bias is bias in the form of people inaccurately recalling their beliefs or experiences, thus delivering inconsistent responses due to unreliable memory. A measure implemented to reduce such bias was interviews with the teachers throughout the semester and post-observation conversations conducted some hours after their lecturing sessions and, in some cases, immediately after. On type of bias could be in the form of influence from the researcher/interviewer. The presence and behavior, both verbal and non-verbal, could impact the interviewees' responses. The interviewees may feel the need to conform to the expectations or opinions of the researcher. Moreover, the analysis of the data by the researcher means that the researcher introduces subjectivity in how the data were analyzed. Additionally, the cultural context of Higher Education, Norway, mathematics, and statistics may make the study not generalizable outside of this context or discipline. The transition to ALSs might present challenges in different cultural, institutional, or disciplinary contexts.

In addition, all the studies could be expanded, as explored earlier. Such expansion could be following the teachers for a longer period of time across several iterations of the same course (Aga 2023a), assessing the impact on student learning outcomes for cohorts in ALSs, compared with a control group (Aga 2023b), and extensively designing different tasks (procedural, contextual and conceptual) and assessing their impacts on the students' learning (Aga 2023b).

3.5.2 Conclusion

A large part of the students' reflections was concerned with what the teachers could do better to benefit the students. Moreover, a large part of the teachers' reflections was on what support could be offered to teachers for them to perform better.

While students need to be supported by teachers, teachers need to be supported by their institutions, and the institutions need to be supported by the government. It is essential that all these elements: students, teachers, institutions, government, and more, communicate the need

for support they feel they have. The teachers did not provide the support the students needed, not out of neglect or indifference, but because they were unaware of the students' specific needs. It was necessary for teachers and students to communicate more closely for both groups to support each other better. Thus, teachers need to instruct students and encourage communication with the students. While the teachers also need to listen and communicate with the institutions about how they can support the teachers. That the teachers work to change the institution to support them better is a lot to ask of the teachers alone. Therefore, it is vital that support is viewed systemically and considered a collective responsibility for all participants and institutions.

For research on these topics to contribute to the development of systemic change, it is essential that the researchers work to communicate their findings and push for changes that will benefit the development and use of learning activities and learning spaces, and higher education.

3.5.3 Thesis Summary

Overall, ALSs have a great potential for improving education but do not guarantee improved quality. There are many ways to use ALSs, and while there is likely not one single best way to use such spaces, some ways are more beneficial than others. A first step to improving education through better use of ALSs should be through understanding such spaces. Here, a qualitative and exploratory study has been conducted to develop a better fundamental understanding of both teachers' and students' perceptions of their experiences as they transitioned to ALSs. However, designing further studies, such as quantitative ones, should further strengthen the certainty and objectivity of the knowledge about ALSs. The author hopes that this thesis and the material presented here can be used to benefit teachers, students, researchers, and others both directly and indirectly in improving education.

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Paper I

Challenges and Motivation for Teachers Transitioning to Active Learning Spaces

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Challenges and motivation for teachers transitioning to active learning spaces

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ABSTRACT

Research indicates that active learning and Active Learning Spaces (ALSs) may improve student learning. Four teachers in mathematics and statistics at a Norwegian university are examined as they transition to ALSs. The teachers' experiences were analyzed using grounded theory which resulted in the three categories presenting what the teachers perceived as significant challenges to overcome when transitioning to the ALSs. The three categories are *Engaging Students*, *Building Student Relations*, and *Developing Teaching Strategies*. These categories were examined for how the teachers addressed the challenges and their motivation for using ALSs. The teachers felt it was necessary to handle all three categories well to benefit from the ALSs, further motivating active learning and ALS use. However, poor handling of the challenges reduced the teachers' motivation. This study was guided by action research and is part of a more extensive study that looked at the student perspective.

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1. Introduction

1.1. Research context

This paper focuses on the reflections and feelings of teachers striving to adopt new learning methods in a new learning environment. While there is an increasing amount of research that supports that active learning may increase student learning outcomes, it is also essential to remember that there is no guarantee that active learning will increase student learning outcomes (Freeman et al. 2014). Indeed, not all ways of doing active learning are equal, and changing the way and space to teach is inherently risky (Kvan and Fisher 2021). A better understanding of how to help teachers transition to active learning and Active Learning Spaces (ALSs) may mitigate teachers' perception of risk related to changing their practices and increase students' learning opportunities (Jones and Fevre 2021). Indeed, learning more about how teachers transition and struggle with such transitions would be beneficial for providing better support and professional development to teachers, which in turn may secure better learning outcomes from active learning. Thus, a continuation in researching and supporting the transition to ALSs is essential to improve student learning outcomes further and to confirm if teachers' perceptions of the transition process are similar in a mathematical context and the Nordic university culture as reported elsewhere in the literature.

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1.2. Active learning

Active learning takes on various forms, such as problem-based learning, flipped classroom, peer instruction, or simply asking students to solve problems individually or with peers during class (Barell 2006; Mazur 1997). Active learning is here defined as teaching methods that allow students to participate actively in the learning process beyond listening, thinking, and notetaking (Prince 2004). While active learning sometimes entails homework, here, the definition only includes classroom activities (Bonwell and Eison 1991). There is an increasing amount of evidence that active learning outperforms conventional lecturing as a teaching method (Crouch and Mazur 2001; Deslauriers, Schelew, and Wieman 2011; Deslauriers and Wieman 2011; Fraser et al. 2014; Freeman et al. 2014; Hake 1998; Michael 2006; Springer, Stanne, and Donovan 1999). Active learning can also change students' attitudes toward learning and increase motivation (Cohen et al. 2019). How to best implement active learning is a growing topic in the literature (Bernstein 2018; Johnson et al. 2021). Active learning is not always successful or unproblematic. There is evidence that teacher implementation (Andrews et al. 2020), students not appreciating or understanding the purpose of the active classes (Deslauriers et al. 2019), or poor collaboration between peers (Deslauriers et al. 2019) may negatively influence learning outcomes from active classes.

1.3. Active learning spaces

Increased awareness of active learning has led to reflection on the spaces where such teaching strategies are performed (Finkelstein et al. 2016). Indeed, many universities have invested in learning spaces that facilitate students to be active and engaged during the learning sessions to improve further the benefits of active learning (Oblinger 2006). These new learning spaces have many names, such as 'Active Learning Classroom,' 'Next Generation Learning Space,' 'TEAL,' and 'SCALE-UP,' here referred to as Active Learning Spaces (ALSs) (Baepler et al. 2016; Fraser et al. 2014). ALSs are here defined as spaces designed with the intent for students to learn actively (see Figure 1 for illustration and section 2.2.2 for description). They typically include tables large enough for small group discussions and technology to facilitate collaboration.

There is evidence that active learning in ALSs further increases students' learning outcomes (Baepler et al. 2016; Brooks 2011; Brooks and Solheim 2014; Fraser et al. 2014; Taylor 2009). The benefits of such spaces have been attributed to the design enabling enhanced interaction between students (Brooks 2011). The design of the space, and the expectations that the users of the ALSs get, have been argued to promote mindsets that support the use of active learning and work to create a social climate that improves student learning outcomes (Walker and Baepler 2018).

Evidence suggests that teachers with epistemic beliefs in favour of active learning succeed better in ALSs (Lasry, Charles, and Whittaker 2014). First-time users of ALSs frequently did not change their teaching practices, i.e. teachers that lectured continued to do so (Carr and Fraser 2014). Nonetheless, teachers who did use active learning in ALSs found incentives to allow for more flipped classroom teaching (Van Horne et al. 2014).

1.4. Challenges when adopting and adapting to ALSs

Many researchers want to see more evidence-based teaching practices (Handelsman et al. 2004; Henderson and Dancy 2007; Stains et al. 2018). However, some concerns hinder teachers from adopting and adapting to ALSs. These concerns include the preparation time required to implement, the use of classroom time, as well as concerns about covering the curriculum, student resistance, the efficacy of active learning, and even how their teaching will be evaluated (Andrews et al. 2020; Dancy and Henderson 2005; Felder 2007, 2010; Finelli, Richardson, and Daly 2013; Froyd et al. 2014; Vuorela and Nummenmaa 2004). In addition, teachers report challenges in adapting to ALSs, such as overcoming student distractions and managing a new teaching role (Petersen and

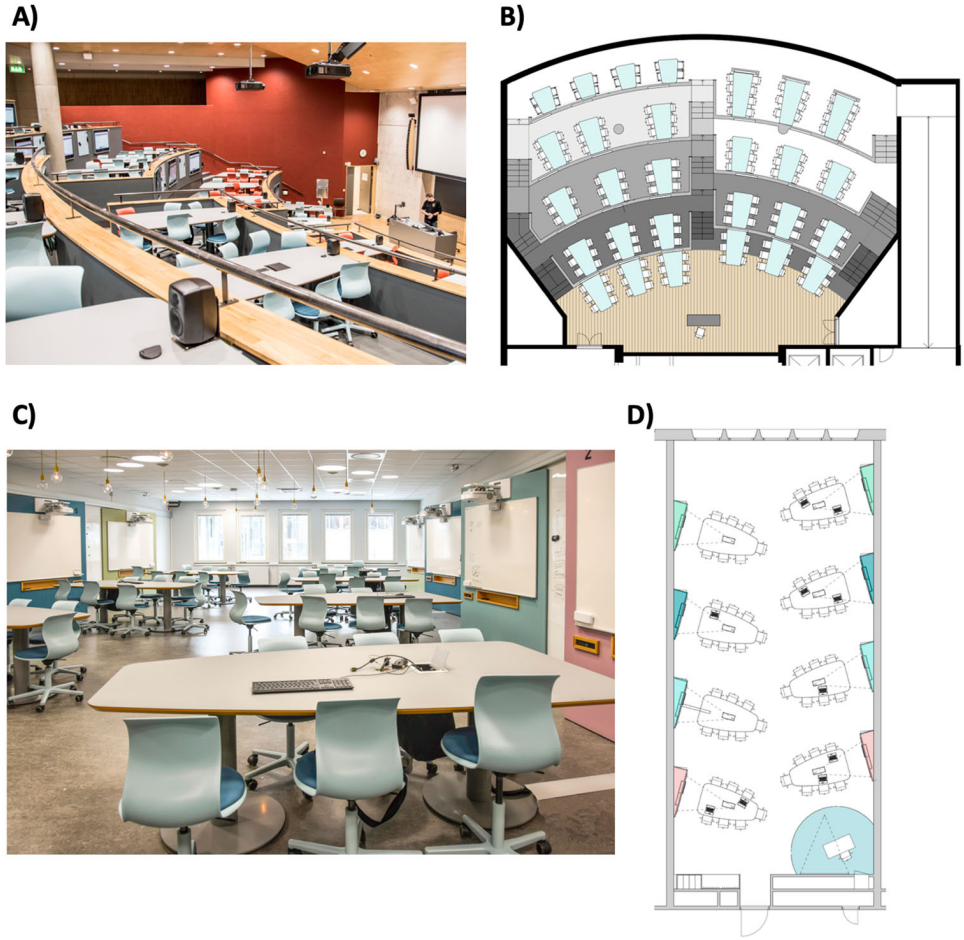

Figure 1. Illustrations of R2 (panels A and B) and SMIA (panels C and D), provided by Eggen Arkitekter AS.

Gorman 2014), lack of departmental support (Dancy and Henderson 2007; Fagen, Crouch, and Mazur 2002; Felder and Brent 1996; Silverthorn, Thorn, and Svinicki 2006; Turpen, Dancy, and Henderson 2010), students not appreciating or understanding the purpose of the active classes (Deslauriers et al. 2019), and poor collaboration between peers (Deslauriers et al. 2019).

Professional development can be an effective tool to support teachers in adopting and adapting to ALSs (Garet et al. 2001; Sorcinelli 2002). Teachers have reported that they would like professional development such as classroom observation, discussion with peers, or an experienced mentor to guide them through the implementation process when transitioning to the ALS (Finelli, Richardson, and Daly 2013).

1.5. Opportunities for adopting and adapting to ALSs

ALSs may provide new affordances, i.e. new opportunities for the teachers in how they structure their classes and how they interact with their students. In addition, ALSs can change teachers' expectations of what their classes should look like (Brooks 2011). Indeed, these affordances and expectations from the ALSs can make the active learning teachers are already doing even better (Brooks 2011) and make teachers interested in doing more active learning (Van Horne et al. 2014).

Furthermore, teachers can find joy and more fulfilling teaching experiences through active learning by helping students appreciate discovering something for themselves (Frank 2020). Teachers' enjoyment may lead to better student learning outcomes (Hernik and Jaworska 2018). Additionally, ALSs may change the social context of the classrooms towards fostering improved educational alliance and communication between teachers and students (Baepler and Walker 2014). Indeed, adopting active learning and ALSs could be a positive experience for teachers. Furthermore, there exist measures to encourage academics to focus on university teaching, for example, the focus on a national level on active learning and ALSs (Kunnskapsdepartementet 2017), and there also exist an effort to highlight excellent teaching practitioners at the Norwegian University of Science and Technology (NTNU) (Raaheim et al. 2020).

Nevertheless, there appear to be many opportunities left for institutions to encourage academics to focus more on their teaching. Graham (2022) reports that since 2019 there has been no significant change in academics' perceptions of their universities' underlying values and priorities with respect to rewarding university teaching, i.e. academics view university teaching as persistently undervalued (Graham, 2022). The use of the Expectancy Value Theory to evaluate teachers' motivation to adopt active learning practices found that teachers' adoption of such teaching strategies was often hindered by their perception of barriers such as fear of negative student response, a lack of time, a lack of support, and more (Finelli, Richardson, and Daly 2013). Indeed, it is still of interest to learn more about teachers' motivation to adopt and adapt ALSs, using theories such as the Expectancy-Value Theory (EVT) that acknowledges that teachers' motivation is influenced by both their perception of the difficulty of a task and their perception of the value of the task (Atkinson 1957; Wigfield and Eccles 2002; cf Section 2.1.2). Such research could be used to inform improved faculty professional development and administrative change plans.

1.6. Research questions

According to the Interaction Equivalency Theorem (Anderson 2003; Miyazoe and Anderson 2010; see Section 2.1.2), some form of interaction is necessary to obtain deep and meaningful learning. Active learning and ALSs can, but do not have to, support high-level interactions. Ample evidence suggests that active learning and ALSs may improve student learning outcomes, however, here, the focus is on how the teachers perceived challenges in transitioning to an ALS. Such an examination could clarify potential pitfalls in improving educational practices and highlight motivational obstacles to teachers wishing to use ALSs.

The research questions are:

(1) What do the teachers perceive to be significant challenges to overcome when transitioning to ALSs?
(2) What did the teachers do to overcome the challenges?
(3) How do the teachers perceive that their motivation and their challenges mutually affect each other?

Research question (1) aims to identify what the teachers perceive as significant challenges when transitioning to ALSs. Research question (2) explores what the teachers did to overcome the challenges, specifically what tools they used to overcome them.

Finally, research question (3) is concerned with understanding how the challenges and the teachers' motivation mutually affect each other to learn how teachers' motivation impacts their success with transitioning and how their perception of the challenges impacts their motivation to transition.

Interactive Action Research (IAR) (section 2.1.1) was used to make the teachers committed to transitioning to the ALSs by supporting them in overcoming minor challenges and looking at what they felt were significant challenges as they transitioned to the ALSs. The data material consisted of

individual semi-structured interviews, group reflection conversations, and post-observation conversations (see Table 2). Classroom observations were also indirectly used to provide further talking points with the teacher. Using grounded theory (cf Section 2.3.2), categories describing significant challenges for the teachers to overcome when transitioning to the ALSs were identified. These categories answered research question (1), and their structure is illustrated in Figures 2–4. Once identified, the categories were examined for answers to research question (2), what teachers did to overcome the challenges, and research question (3), how the teachers perceived the mutual relationship between the challenges and their motivation to use ALSs. For research question (3), the EVT was used to analyze the teachers' motivation (Atkinson 1957; Wigfield and Eccles 2000; cf Section 2.1.3).

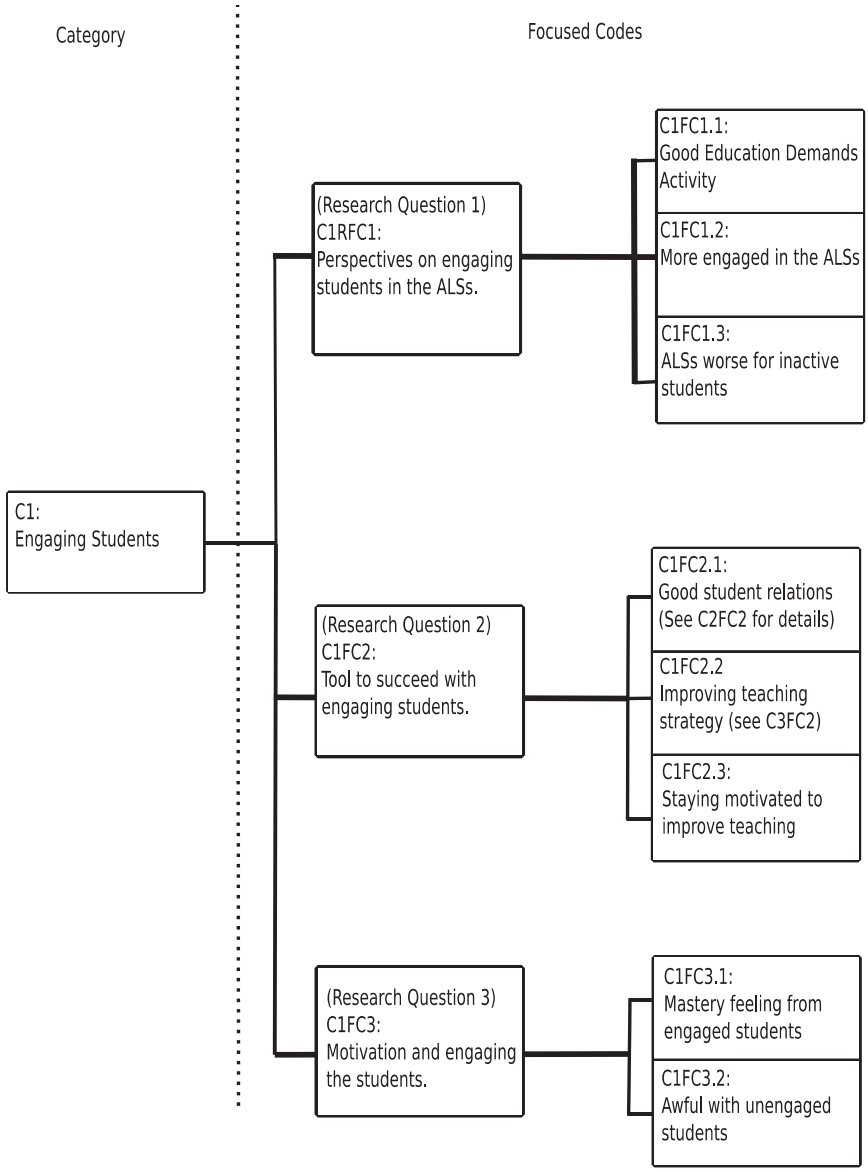

Figure 2. The focused codes show how the teachers perceive the challenge of engaging students. Research questions 1, 2, and 3 are respectively addressed by focused codes (FC) 1, 2, and 3.

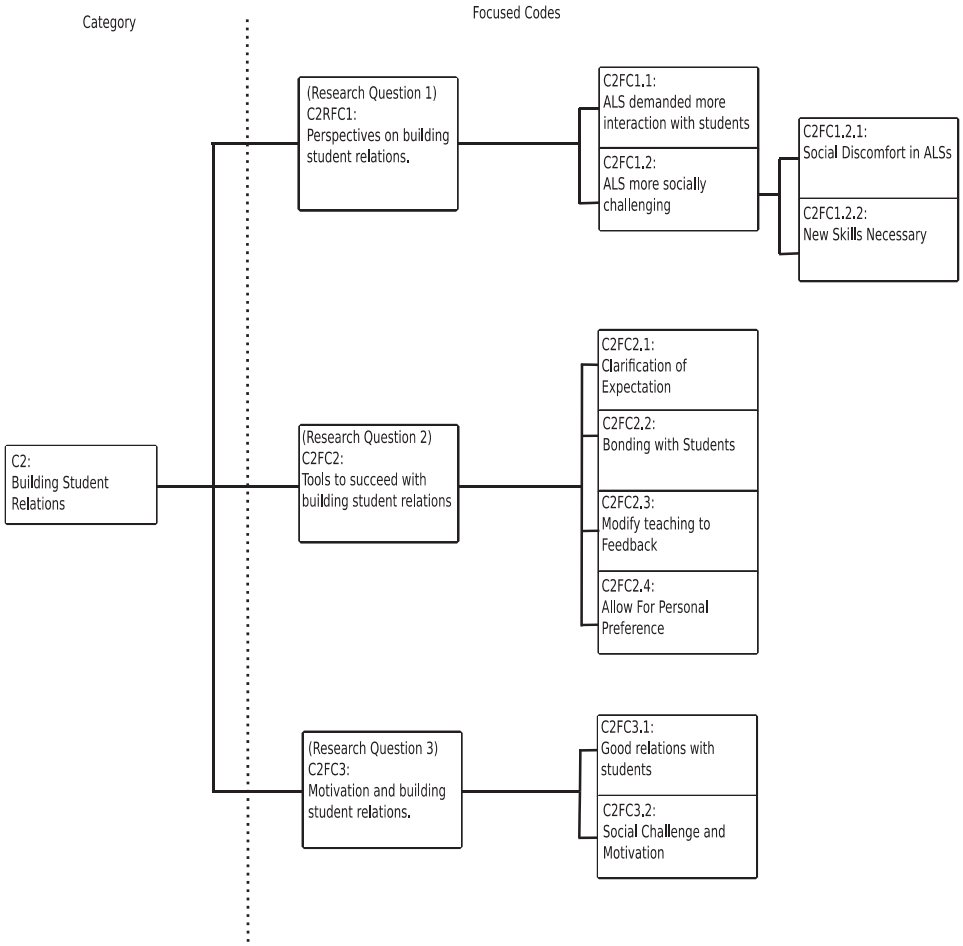

Figure 3. The focused codes show how the teachers perceive the challenge of building student relations. Research questions 1, 2, and 3 are respectively addressed by focused codes (FC) 1, 2, and 3.

The findings here may also be unique to the research context, i.e. mathematical and statistical subject matter and higher education in Norway. Of note is that Norwegian culture may be described as similar to other western cultures but with higher pressure on conformity (Avant & Knutsen, 1993).

2. Materials and methods

2.1. Theory

2.1.1. Interactive action research

Action research is a methodology often used in educational research that seeks to improve practice and explain it (Elliot 1991). It seeks to change and transform practitioners' practices, their understanding of their practice, and the conditions in which they practice (Kemmis 2009). There are many subcategories and ways to categorise action research, e.g. technical action research, practical action research, and IAR (Postholm 2007). By Postholm's definition (2007), IAR denotes a form of action research that focuses on researchers and practitioners meeting in an equal relationship, where the researcher has experience from the research field and works to develop the field of practice as well as to research this practice. Furthermore, IAR allows the researcher to offer thoughts on

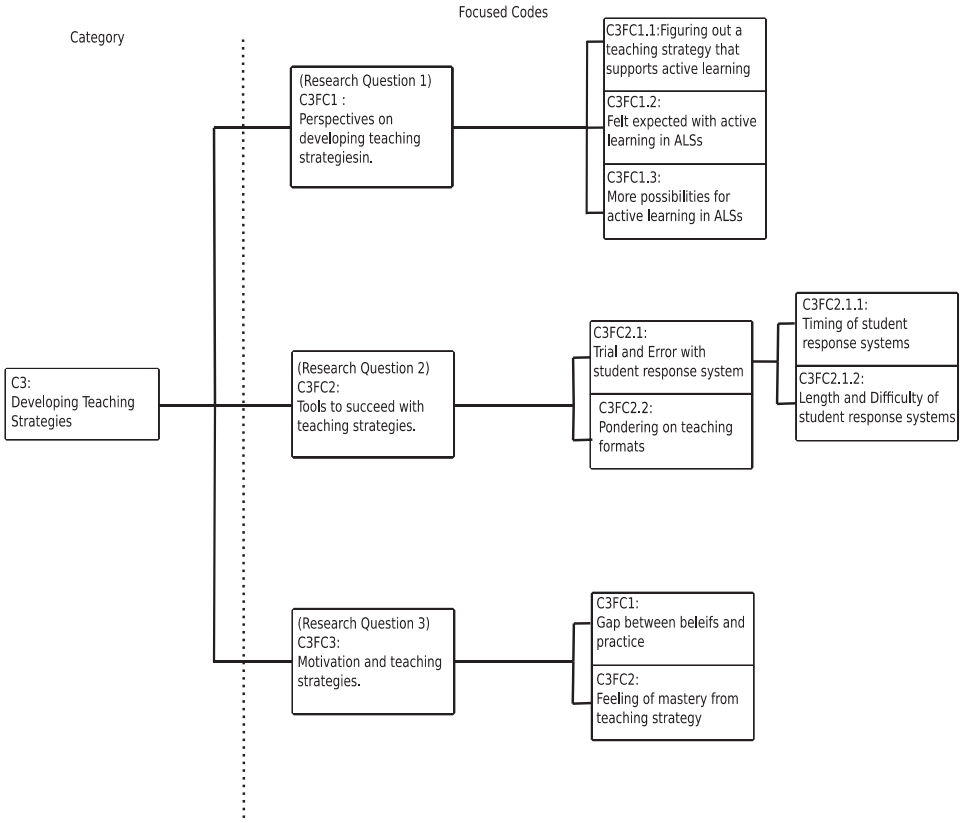

Figure 4. The focused codes show how the teachers perceive the challenge of developing teaching strategies. Research questions 1, 2, and 3 are respectively addressed by focused codes (FC) 1, 2, and 3.

teaching strategies and to probe for the practitioners' opinions on the challenges they encountered during the change in practice that is being researched.

2.1.2. Expectancy-value theory

Looking at the teachers' perceptions of transitioning to the ALSs can inform how one can motivate teachers to change their teaching practices towards using active learning and ALSs. Thus, the identified challenges will be used to examine teachers' motivation as they adopt active learning and adapt to ALSs. The Expectancy-Value Theory (EVT, Atkinson 1957; Eccles, Wigfield, and Schiefele 1998; Wigfield and Eccles 2002), is used as a framework for categorising achievement motivation. According to EVT, an individual's motivation for a task depends on their expectancy of accomplishing the task and the value they attribute to achieving it. The expectancy category consists of the ability self-concept, in this case, the teacher's belief in mastering the task, and the task difficulty, which is *their* perception of its difficulty. The value category consists of the attainment value (the subjective view on the importance of doing well), the intrinsic value (the anticipated enjoyment), the utility value (the usefulness for future plans), and the cost (e.g. effort, loss of opportunity, or emotional cost). Factoring teachers' motivation into the elements suggested by EVT offers a deeper understanding of the teachers' challenges.

2.2. Research design

This study is a part of a more extensive study that also looks at the students' perspectives of the teaching environment that the teachers in this study facilitated. The students' experiences were

investigated through focus-group interviews, surveys, and classroom observations and will be further explored in a later paper. The whole study was conducted during the fall semester of 2019 at NTNU.

A recently completed educational development project at the Norwegian University of Science and Technology (NTNU), Technology Education of the Future (Norwegian acronym FTS), established a set of principles for the future development of science and engineering education at NTNU and these principles have been adopted by NTNU's Rector as a platform for future educational development (Øien and Bodsberg 2021; Øien, Bodsberg, and Lyng 2022). The three principles concerning the pedagogical learning environment are of interest in this context: contextual learning, student-active learning, and pedagogical competence development for the teaching staff. If we aim to transform science and engineering education, we need to do more than merely add or update subject content. We need to rethink how education is designed. Central to this ambition is developing the teaching staff's pedagogical competencies and understanding their challenges to design appropriate support for them and the students (Øien, Bodsberg, and Lyng 2022).

2.2.1. The participants

The participating teachers were interested in but had no prior experience using ALSs. Four teachers participated in the study (see Table 1). It was considered that between 3–6 teachers for a research project of this size struck a balance between data and depth, where more teachers allowed for more data, but fewer teachers allowed for more depth in the teachers' reflections. It turned out that four was the number of teachers available in relevant courses that were interested and possible to fit into ALSs in this period. The courses taught were two statistics courses, one for second-year engineering students and one for second-and third-year science students, one calculus course for

Table 1. A summary of the different teachers learning spaces, teaching activities, experiences and preferences.

	Andy	Bob	Christoffer	Daniel
Active Learning Space	R2	R2	SMIA	R2
Norwegian Native Speaker	Yes	Yes	No	No
Experience teaching at NTNU	30+	30+	0–10	0–10
Age	50–70	50–70	30–50	30–50
Course	Statistics	Calculus	Statistics	Numerical Mathematics
Students	Engineering	Engineering	Science	Science & Engineering
The preconception of AL and ALSs	Positive	Positive	Positive	Positive
SRS as active learning	Yes	Yes	Yes	Yes
Mini Exercises as active learning	No	No	No	Yes
Exercise Session as active learning	No	No	Yes	No
Previous experience with active learning	Yes	Yes	No	No
Wants to continue with active learning	Yes	Yes	Yes	Yes
Previous experience using ALSs	No	No	No	No
Wants to continue using ALSs	Yes	Weak Yes	Yes	No
Wants to design teaching to allow for more student activity	Yes	Unclear	Yes	Unclear
Initial change to their teaching	Committed more to AL	Moving more around the space	Changed to active learning-focused class (see 3.3)	Started doing more AL
Main challenges of using the ALSs	Engaging the students	Balancing covering the curriculum and active learning	Developing and using a new teaching strategy	Building student relations due to social discomfort

first-year engineering students, and one numerical mathematics course for mostly master of technology students. All the teachers in this study were given pseudonyms. The teachers, Andy and Bob, were experienced users of a Student Response System (SRS) (Nicol and Boyle 2003; Draper and Brown 2004; Dufresne et al. 1996; Trees and Jackson 2007). The teachers Christoffer and Daniel had some experience trying to engage and activate students from their lectures through questions and discussions, but no prior experience with SRS, flipped classroom, problem-based learning, or other developed active learning strategies.

In the study, all the teachers used SRS-questions; one used mini-exercises, and another used exercise sessions (see Table 1). The SRS-questions were typically used for 2–3 questions every 45 min. Each SRS-question session lasted around 2–6 min. The teacher asked a question and gave the students time to talk, problem-solve and answer, after which the teacher presented the solution. The mini-exercises consisted of 3–4 questions that the students got roughly 15 min to answer before the teacher presented a solution. The exercise session lasted 2×45 min. The students worked on a lengthy task divided into smaller subtasks. The teacher delivered an introduction to the class, an explanation of the subtasks during the session, and a summary of the task at the end while being available for questions during the remainder of the session.

2.2.2. The active learning spaces

The ALSs used in this study were developed between 2016–2018 at an institutional level for all teachers at the university to use. They have been developed as a pilot project that corresponds with NTNU's and the government's ambition to have more active learning and spaces that accommodate such learning (Kunnskapsdepartementet 2017). There are still relatively few ALSs at the university compared to conventional lecturing spaces; however, these ALSs have become very popular among teachers and are hard to book.

The participating teachers used two ALSs named R2 and SMIA (see Figure 1 for illustration). The bigger space, R2, was used by three teachers and could fit up to 160 students. The smaller space, SMIA, was used by one of the teachers in this study and could fit up to 50 students. Both spaces retain some division between students and teachers through a designated teacher area. The spaces also feature tables designed for small group interactions while keeping enough space for teachers to walk around the room among the students. While SMIA is a flat room, R2 is levelled (see Figure 1). Furthermore, both spaces feature educational technology such as Wi-Fi, a whiteboard for each student group, microphones, and a control panel for managing technology at the teachers' desk. Additionally, R2 has a shared digital screen for each student group, while SMIA has an Interactive Whiteboard for each group.

2.2.3. Preparing the teachers

In order to enter into an equal partnership with the four participating teachers and explore their perceptions surrounding the challenges of transitioning to teaching in the ALSs, the research project was guided by the IAR methodology. Following advice from IAR (Postholm 2007), an essential aspect of my role was establishing a comfortable environment where the teachers felt safe sharing their experiences and reflections. Typically, when the teachers had nothing more to share on a topic, I shared findings and ideas from the relevant literature and theory to contrast or highlight a point and get a deeper understanding of the teachers' perspective. Additionally, the teachers were influenced actively to participate in the research project in the following ways:

(1) Before the teachers chose to transition to the ALSs and participate in the research project, I made the case to the teachers that active learning and ALSs could benefit the quality of their teaching. I clarified that the research project was built around data collection while supporting a change to improve practice and that I would be available to assist them as a 'research expert' as they transitioned to the ALSs. This was emphasised to make the transition seem more manageable and motivate the teachers to enter the research project.

(2) After the teachers committed to the research project, I influenced the room selection process to guarantee that the teachers were admitted to the ALSs.
(3) I further offered input to the teachers throughout the research period on ideas as they transitioned and encouraged the teachers to discuss active learning and ALSs with each other. This input was offered to improve the chance that the change would benefit the teachers and the students and reveal the more significant challenges they encountered.

Overall the discussions aimed to make the teachers share their emotions and thoughts on how it was to adapt to the ALSs. However, particularly for the early discussions, the teachers requested more information on possible ways to do active learning and how to teach in the ALSs. Hence, the researcher provided information on teaching strategies, such as problem-based learning, flipped classroom, and peer instruction. Different tools to make the students active such as grouping them in varying ways, diverse tasks, and SRSs, were also discussed. When explicitly asked by the teachers to do so, the researcher also offered opinions on matters related to the ALSs. It was made clear that such opinions were subjective and that there were other outlooks on the matter.

One such opinion was that for first-time users of active learning and ALSs who might be worried about the workload that came with transitioning to the ALSs, an SRS might offer a softer transition to the ALSs than, e.g. problem-based learning or flipped classroom. Such input may have impacted teachers' reflections on teaching strategies. However, it was also stated that it was possible to opt for a teaching strategy more similar to flipped classroom or problem-based learning, and that the teachers would be supported and put in contact with other more experienced users and practitioners of their chosen strategy to help them through their transition.

The sense of a shared community, possible support, and opportunity to talk to the other teachers seemed to positively impact the teachers' outlook on ALSs and active learning and may have impacted the results of this paper. Indeed, without the interference, the teachers would most likely not have transitioned to the ALS at this time.

2.3. Data collection and analysis

2.3.1. Data collection

To be able to answer the research questions, the following data was collected (see Table 2 for a summary):

- **Individual semi-structured interviews**; focused on the teachers' perception of challenges before and after teaching in the ALSs. For each teacher, one interview was conducted before the teaching started (pre-interview), and one was conducted after the first semester of teaching in the ALSs (post-interview). These interviews established a baseline for the teachers' perceptions of the challenges of transitioning to the ALSs, and how their perceptions changed before and after ALS use.

Table 2. A summary of all the data material used in this study.

Data-source	*Data-type*	*Group-size*	*Number of Times*
Individual semi-structured interviews	*Audio (Transcribed)*	*The researcher + One teacher*	*One Pre-Interview Per Teacher One Post-Interview Per Teacher*
Group Reflection Conversation	*Audio (Transcribed)*	*The researcher + 2–4 teachers*	*Five times – varying composition of teachers*
Classroom Observation (indirectly used)	*Notes*	*The researcher + Teacher and Class*	*4–6 times per teacher*
Post-observation Conversation	*Audio (Transcribed)*	*The researcher + One Teacher*	*1–2 times per teacher*

- **Group reflection conversations** were regular physical group conversations where the teachers shared their concerns about the difficulty of teaching in the ALSs with each other and the researcher. As encouraged by IAR (Postholm 2007), the researcher actively influenced the teachers by facilitating dialogue and making suggestions for reading materials and teaching strategies. The teachers were encouraged to share their successes and challenges.
- **Classroom observations**; the researcher observed some of the teachers' classes. These observations were not directly used in the analysis but provided talking points for later conversations. The conversations influenced what the teachers did in later classes.
- Finally, in **Post-observation conversations,** the teachers talked about their performance in class shortly after being observed. More specifically, while fresh in memory, the researcher discussed how the teachers perceived the challenges of the particular class. These post-observation conversations aided the researcher in comparing his experience from the observations with the teachers' first-hand experience from the classroom.

The different data sources were a part of an extensive iterative reflective process where the various data sources influenced one another. The researcher influenced the teachers' practices through interactions, giving rise to new discussion topics. Furthermore, the researcher took measures to ensure that all sessions were safe and comfortable places where the teachers could share their experiences and thoughts, both good and bad, related to teaching in the ALSs.

2.3.2. Data analysis

To address what the teachers perceived to be significant challenges to overcome in transitioning to ALSs (Research Question 1), the constant comparative method was used as a part of grounded theory (Strauss and Corbin 1998) to find any underlying structures in the transcribed data material from the individual interviews, the group reflections, and the post-observation conversations. The classroom observation notes were not analyzed but used as talking points in later conversations and interviews. The constant comparative method is used to structure the data material through an iterative process of rereading and analyzing the data material. In order to draw out the results from the data, each sentence was given a brief name that classified the topic. Non-pertinent elements of the text were removed. Text that was unclear whether it was relevant or not was temporarily given its own colour and name to be reevaluated at later stages. The analysis was gradually built up from bottom to top through rereading and re-analyzing the text to see how the text could be sorted and named differently. When all pertinent text was line-by-line coded and appropriately named, the analysis continued towards creating focused codes by grouping lines of similar topics together. In addition to being named, these focused codes were given colour codes. Creating focused codes consisted of further rereading and re-analyzing to test and modify the focused codes continuously. When the sorting of the focused codes was fixed, and there was no need for further changes, the focused codes were, in turn, grouped into categories. The focused codes and categories are presented in Figures 2–4. The analysis yielded three categories relating to research question (1): Engaging Students, Building Student Relations, and Developing Teaching Strategies (see Section 3.1–3.3). The underlying focused codes that resulted in each category are presented in Figures 2–4.

While coding for research question (1), wether the data material could highlight other themes was also considered. Indeed, there were discovered tendencies througouht the coding process of research question (1) that could highlight the themes of research questions (2) and (3). After the coding for research question (1) was finished, the codes were revisited and used to finish the formulations for research questions (2) and (3) as well as provide complete answers for these research questions.

For research question (2) it was investigated what sort of content in each of the categories discovered through research question (1) that gave answers to this research question. I.e. when the

Table 3. A summary of the teachers' perspective on their motivation for transitioning to the ALSs. The perspectives are structured using EVT and the three categories identified in research question 1.

	Engaging Students	Building Student Relations	Developing Teaching Strategy
Ability Self-concept & Task Difficulty	It was seen as more necessary to engage the students when in the ALSs. To positively influence students' engagement was seen as challenging and demanded time and effort.	Building good student relations were seen as particularly necessary in the ALSs. The teachers who considered themselves to have good social and soft skills saw creating student relations as an easier task.	The teachers felt that ALSs encouraged them to develop new teaching strategies, which demanded new pedagogical and didactical skills that differed from those used while lecturing.
Attainment Value	The ALSs were viewed to have a positive value if the students were engaged and a negative value if the students were unengaged.	Building student relations were seen as an essential tool to engage the students and made the classes seem more meaningful.	The teachers saw new teaching strategies as valuable to improve student learning outcomes. However, the teachers still felt they needed to cover the curriculum.
Intrinsic Value	Engaged students made teaching more fun. However, it was potentially heartbreaking to have unengaged students in the ALSs.	Good relations with the students made the classes more fun.	The teachers enjoyed aligning their practices with their teaching beliefs. However, struggling with the adaption was a source of dissatisfaction.
Utility Value	Transitioning to the ALS was perceived to have a negative utility value as teachers feared that poor perceptions from students or peers could have negative consequences.		
Cost	There was an emotional cost to transitioning to the ALSs and being uncertain if the students would engage.	There was an emotional cost to trying to connect to the students as the teachers feared being perceived poorly.	Transitioning to a new teaching strategy demanded time and effort. The teaching strategy is also needed to fit the ALSs.

teachers talked about the specific challenge of engaging the students, how did they talk about overcoming this challenge.

A similar process was used for research question (3), but this research question also introduces the concept of motivation. The teachers' motivational experiences and reflections were examined using EVT and structured into categories, as seen in Table 3.

3. Results

The grounded theory helped identify three categories of what the teachers perceived as significant challenges when transitioning to the ALSs. The three categories are *Engaging Students*, *Building Student Relations,* and *Developing Teaching Strategies*. Each category contains (1) a description of the perceived challenge and why it was necessary to overcome it to benefit from the ALSs, (2) a presentation of how the teachers reflect they could overcome the challenges, (3) comments on how the teachers perceived that the challenges and their motivation to transition to the ALSs mutually affect each other, and, finally, (4) a figure presenting the structure of each of the focused codes for the category (see Figure 2–4). The teachers' reflections were then sorted with respect to the three categories and the motivational factors from the expectancy-value theory, see Table 3. For Table 3, the *ability self-concept* and *task difficulty* categories were merged into one, as the discrepancies between the teachers' views on task difficulty and their belief in mastering the challenges were still in development.

The teachers reflected more on active learning than ALSs; however, they perceived that using ALSs was the final push for them to do active learning. The transition to ALSs compelled the teachers to reflect more on their active learning practices. The change in physical environment compelled the teachers to act differently as the ALSs afforded new opportunities, such as more readily facilitating student group work and connecting with students through walking around the classroom. Furthermore, the ALSs facilitated more teacher reflection on active learning as they experienced that it was expected of them to go beyond conventional lecturing in these spaces, which in turn made them

reflect more on how they could engage and increase student learning. Indeed, this was quite different from their experiences in the standard lecture theatres, where they felt no inspiration from the space to go beyond lecturing.

The teachers felt that the ALSs were comparable to raked lecture theatres for traditional didactic instruction. However, there were concerns that the oblong shape of SMIA and the wideness of each level at R2 made it hard to see the students, feel a connection with the students, and a concern that the students did not see the teachers well enough. Furthermore, the teachers felt that as the spaces afforded the students to interact, longer lecturing segments were more prone to students distracting each other. However, many teachers considered this a remainder to space out the active learning segments and kept their lecturing segments reasonably brief.

3.1. Engaging students

Engaging Students is the first of the three categories determined by the constant comparative method. Figure 2 shows how the teachers view the challenge of engaging their students. The teachers understood student engagement to mean that the students were paying attention to the teacher and showing curiosity for the subject matter and the learning activities in the class. The teachers laboured to engage their students as they felt that good student engagement was necessary for good student learning outcomes and reported that being in the ALS made them particularly aware of the importance of engagement.

Three key elements influenced the significance the teachers attributed to the challenge of engaging their students. Firstly, the ALS context made the teachers reflect more on the importance of engagement and thus put more pressure on themselves to engage their students. Secondly, the ALSs were perceived to make it easier for students to engage in non-curricular activities, which made it especially important to engage the students otherwise. Finally, the teachers perceived the active classes in the ALS as worse for unengaged students than the conventional lectures. The unengaged students in a lecture were perceived to absorb some of the information presented to them, but the students who refused to engage in the active elements or gave up quickly were perceived to learn nothing. Indeed, the teachers reflected that there is a bigger threshold for students to learn from active segments than from more passive ones.

The teachers used mainly three approaches to overcome the challenge of engaging their students. Firstly, they worked to create a positive and comfortable relationship with the students and explained their teaching strategies' purpose to connect with and motivate the students (see Building Student Relations). Secondly, they chose an appropriate teaching strategy with well-designed tasks (see Developing Teaching Strategy). Finally, they spent time adapting and improving their teaching in the ALSs (see Figure 2 for focused codes).

The teachers reported higher intrinsic values in the ALSs as they perceived that the space increased their students' engagement, which they reflected was likely due to the environment of the ALSs being conducive to them establishing good student contact and interacting more with the students. Daniel reported that active learning and being in an ALS helped him engage his students: 'The biggest success is getting students to reply. I have struggled with that for eight years, but now I can get them to reply … I am happy now.'

The teachers' attainment values of the ALSs were highly related to how they felt their students did in the ALS classes. Indeed, if the students were not sufficiently motivated to work on the tasks, the teachers thought that the ALSs could reduce the student learning outcomes. The teachers reflected that unengaged students would still interact more in the ALSs, but about non-educational matters. Thus, the attainment value the teachers attributed to teaching in the ALSs depended on their expectancy of being able to engage the students. Only some of the teachers were confident enough in their ability to engage the students that they saw the potential benefit of transitioning to the ALSs as guaranteed. The teachers who felt they succeeded in engaging the students reported enjoyment and found the active classes meaningful. Reversely, failing to engage the students was

felt to reduce their enjoyment and add emotional stress (see Table 3). For instance, the teacher who reported the highest social discomfort in the ALS also reported the lowest intrinsic motivation to be in the ALS.

3.2. Building student relations

The second of the three categories is *Building Student Relations*. The structure of the focused codes in this category is presented in Figure 3. The teachers experienced student contact as an essential tool to keep the students engaged. Good student contact was described as being in touch with the students and having a friendly bond between the teacher and the students. Furthermore, good student contact was felt to increase dialogue between the teacher and the students, the quality of the feedback the teachers received from the students, the students' willingness to participate, and the student's ability to stay focused and interested in what is going on in class. However, a significant challenge the teachers perceived when transitioning to the ALSs was that these spaces demanded more interaction with the students, which demanded time and was socially challenging for some teachers. Indeed, for the teachers that found it challenging, it could trigger their social discomfort and demand more time to refine their skills in connecting with the students. Daniel reflected that it was socially challenging for teachers and students, but for some more than others: 'But I do sympathize with the poor introverts that have to go to do group work all the time. My heart goes out to them. I do feel for them. I am one of them.'

With some variations, the teachers used the following approaches to overcome the challenge of building student relations. They clarified what is expected of the students in the course as well as in the class. Secondly, they worked to create an atmosphere of trust by walking around the classroom, talking with the students, and encouraging them in their work. Finally, the teachers demonstrated interest in their students by listening to their experiences and adapting their teaching to the students' preferences when possible. The teachers felt that these approaches had to be used in a natural way, i.e. the approaches needed to match their intrinsic values and ability self-concept to connect with the students successfully. The teachers' strategies to overcome the challenges were similar to findings on reducing student resistance to active learning, such as in Finelli and Borrego (2020). Furthermore, the teachers also felt that the ALSs stimulated them to try more strategies to engage their students, similar to what was found in Johnson et al. (2021).

The teachers felt that the enhanced feedback from good student relations guided them in improving the quality of teaching. In turn, when the teaching quality was good, it was perceived to be easier to build good student relations, thus creating a positive cycle. Nonetheless, the teachers sometimes perceived the students' feedback as insincere or un-reflected and instead focused on the students' desire for comfort than their interest in learning. Thus, to detect quality feedback, the teachers chose to use several complementary feedback sources, such as responding to in-class questions (including the SRS questions), observing the students working, and talking with the students in and after class. Andy reflected this as a challenge: 'It is hard to say, with any certainty, how good the teaching actually has been … talking with the students helped get good feedback.'

The four teachers reported that the ALSs afforded more opportunities and increased expectations for interacting with their students, influencing their motivation. The socially comfortable teachers reported increased attainment and intrinsic value from the ALSs. Contrary, the self-reported socially uncomfortable teachers reported that the ALSs increased their stress levels. This stress impacted teachers' motivation by making them perceive teaching in ALS as having a greater task difficulty and a lower intrinsic value. Indeed, the more socially uncomfortable teachers reported being more preoccupied with how they were perceived by their students, which in turn inhibited their support of the students. Bob perceived student relations to influence students' motivation positively: 'I really think the contact with the students is important. With good student contact, I think it becomes a lot more motivating for the students.'

One teacher reflected that he underestimated the relationship between the ALSs and his motivation, partly because he found it socially uncomfortable and challenging to teach in this space. This teacher reported that the social discomfort made him perform suboptimally, leading to a drop in attainment value, intrinsic value, and perceiving the task difficulty of adapting to the ALS as higher. The teacher did not want to teach in ALSs after this experience (see Table 3). The teachers reflected that guidance from others and time to figure out how to adapt to the ALSs were appreciated and necessary to succeed.

3.3. Developing teaching strategies

The third and last category identified was Developing Teaching Strategies. The teachers' reflections on what was challenging with developing a good teaching strategy are illustrated in Figure 4. The teachers perceived that finding and adapting a teaching strategy suitable to them and their students was a significant challenge that needed to be overcome when transitioning to the ALSs. To succeed with their teaching strategy, they felt that it needed to fit with their personal preferences and skills, such as constructing good tasks and allowing for engaging their students in a way that was socially comfortable for them as teachers. The development of their teaching strategy was reported to be a personal journey of trial and error that was sped up by teaching in the ALSs, where it was felt to be expected to use active learning. The teachers felt that maintaining good intrinsic and attainment values towards adapting ALSs depended on their mastery of adapting to a new teaching strategy.

While pondering on how to overcome the challenge of developing teaching strategies, the teachers reflected that there were two main approaches to implement active learning into their classes. The first way, referred to as *active learning enhanced lecture,* was augmenting a regular lecture with more active learning. The second way, an *active learning-focused class,* embraced a pedagogy form centred around active learning such as flipped classroom or problem-based learning. While the teachers reasoned that active learning-focused classes had the highest potential for attainment value, they still often chose to teach using active learning-enhanced lectures. The teachers felt more comfortable with active learning-enhanced lectures than active learning-focused classes, as they could keep lecturing while gradually adapting to teaching with active learning. Furthermore, the teachers viewed it as their responsibility to personally cover the curriculum for the students. Covering the curriculum was perceived to be easier with lecturing than with active learning, and for some of the teachers, their high attainment value attached to covering the curriculum prevented them from fully committing to active learning. That is, while the teachers still believed in active learning, they did not practice it as much as they wanted to due to the perceived cost of not covering the curriculum.

For the active learning enhanced lectures, the teachers used SRS. Using the SRS was felt to be an effective way of providing breaks from lecturing, allowing students to help each other, and providing feedback to the teacher. The teachers new to active learning invested time into developing appropriate complex conceptual questions to fit with the SRS-format (Nielsen, Hansen, and Stav 2016). The teachers drew inspiration from peer instruction, creating tasks where students answered 30–70% correctly on the first try (Mazur 1997). Reading the students' moods to deliver the activities at the right time was also seen as essential.

The teachers perceived it more challenging, i.e. a higher task difficulty, to fit active teaching strategies and develop suitable tasks for mathematics than for other subjects. Some teachers reflected that subjects that were perceived as less abstract and more related to everyday experiences were easier to discuss and create group work exercises for, while mathematics being perceived as abstract made it less suitable for group work. Furthermore, they reflected that mathematics often required a significant fundamental understanding of the subject before the students could engage in beneficial interaction. Such perceptions reduced the teachers' motivation to transition to the ALSs. Mathematics was seen as more abstract, less related to students' life experiences, and challenging to engage with beyond working alone. Additionally, the teachers felt that it demanded more time to adapt to making suitable mathematical tasks that fit their teaching methods. They had to shift from mainly

designing procedurally focused tasks to conceptually based tasks. Christoffer summarised one of his main challenges with developing a teaching strategy: 'I have lots of ideas – it could be very cool to do it like this and that – but then I don't since I do not have the extra time I wished I had.'

3.4. Relationships between categories

The teachers felt they benefitted from the ALSs when their handling of the three categories was good. Christoffer, who had good relations with his students, said, 'I think it is a lot easier to interact with the students in SMIA as I can walk from table to table and ask how they are doing – I do not do this in a regular lecturing hall.' Furthermore, good handling of one category increased the teachers' motivation to work on the other challenges and was perceived to make it easier to handle the other categories well. When the teacher mastered a challenge, their intrinsic motivation for working with active learning in the ALSs increased, including their intrinsic motivation related to the other challenges. Furthermore, overcoming a challenge made them perceive active learning in the ALSs as more meaningful, increasing their attainment value for working on the other challenges. Overcoming one or more challenges made the teacher feel that it was more feasible to overcome the other challenges, i.e. success with some challenges reduced the perceived task difficulty for other challenges. Indeed, they reflected that it became easier to manage a challenge well when the other challenges were managed well. For example, good student relations and suitable teaching strategies were viewed as favourable for engaging the students. Engaging the students and having good student relations were perceived to make the chosen teaching strategy more successful, and well-designed activities and engaged students were felt to improve the teachers' relations with the students.

The teachers felt that they could create a positive cycle where good handling of one challenge in the ALSs made the success of the other challenges more likely, while simultaneously increasing their motivation to use ALSs. However, the opposite effect was also made clear: poor handling of any of the challenges was perceived to make the success of the other challenges harder and reduce the teachers' motivation, thus making the teachers less likely to pursue further use of ALSs. Indeed, when a task was poorly handled, the teachers' intrinsic and attainment motivation related to the other tasks were reduced, and the perceived task difficulty of the other challenges was increased.

4. Discussion

In order to enhance and implement active learning, ALSs have been increasingly used (Baepler et al. 2016). Teachers have reported concerns about adopting ALSs, and users of ALSs have reported difficulties in successfully using these spaces (Andrews et al. 2020). These concerns and difficulties inspired further research on teachers' challenges when adopting and adapting the ALSs.

Using expectancy-value theory as a theoretical framework, IAR as a research methodology, and grounded theory for the analysis, I have identified three challenges that teachers transitioning to ALSs perceive to be necessary to handle well if their students are to benefit from the ALSs: 1) Engaging Students, 2) Building Student Relations, and 3) Developing Teaching Strategies. The structure of these challenges is to the author's knowledge novel, but many of the elements and concerns that the teachers mention within these categories, such as difficulty engaging students and lack of departmental support, are mentioned elsewhere (Andrews et al. 2020; Dancy and Henderson 2007; Deslauriers et al. 2019; Jones and Fevre 2021; Turpen, Dancy, and Henderson 2010). When the teachers felt they handled the challenges well, they also felt that teaching with active learning and being in the ALSs had high attainment value and intrinsic value, motivating them to continue using active learning and ALSs. However, for some of the teachers adapting to using active learning and ALSs was perceived to be difficult, demanding much time, and having both a possible emotional cost and a small utility value, adversely affecting their motivation.

While the teachers were aware that the university, as instructed by the government, is interested in teachers using active learning and ALSs (Kunnskapsdepartementet 2017), they felt little to no pressure from their institution to fulfil these demands. However, the teachers were more worried that peers could criticise their effort to do something out of the ordinary if it was unsuccessful (see Table 3). Indeed, these were ordinary teachers that were curious about active learning but otherwise influenced by the research project to transition to the ALSs.

Lasry and co-workers (2014) found evidence that teachers' epistemic beliefs must match student-centred teaching methods for students to benefit from the ALSs. The four teachers in this study had similar reflections and believed that it was necessary with teaching strategies suitable for the teachers to engage the students. Thus, teachers' belief in student-centred teaching may improve the quality of active classes in the ALSs, possibly through increased student engagement. Additionally, Section 3.4 presents how having engaged students may increase teachers' attainment value in active classes in the ALSs, i.e. causing teachers' beliefs to match student-centred teaching. How students are engaged in the ALSs is most likely dependent on a complex interaction between teachers, students, and ALSs. There may also be a bias in who is using ALSs, as teachers that are already successfully using active learning may self-select into ALSs (Morrone et al. 2014), and teachers that succeed in overcoming the challenges may be more likely to continue using ALSs. Thus, it is of particular interest here that the teachers in this study were ordinary and by no means experts in active learning or ALSs. Regardless, it is essential to support teachers to engage their students, build student relations, and develop teaching strategies. Both to improve the quality of active learning in ALSs, and to persuade teachers to transition and continue teaching in ways that support improved student learning outcomes.

Walker and Baepler (2018) found that social context is an underlying factor in how ALSs can improve student learning outcomes. This finding substantiates the four teachers' reflections that building good student relations or creating a positive social context is necessary to benefit from the ALSs. Furthermore, the teachers' reflections on creating a safe and comfortable learning environment that supports interaction and engagement agree with the idea of a 'natural critical learning environment' (Bain 2004; Fain and Kennell 2016).

In a natural critical learning environment, learning activities are most effective when the learner decides to engage because they think it will help them satisfy a need to know or help them to solve a problem that they regard as important, intriguing, or beautiful (Bain 2004).

When working to build good student relations, some of the teachers experienced social discomfort, which was reported to negatively correlate with their self-perceived success in the ALSs. Indeed, putting pressure on teachers to implement ALSs hurriedly may lead to backlash, and one should emphasise that teachers should take the time they need to adapt to new teaching strategies, as has been reflected by Kugel (1993). Additionally, teachers benefit from support as they transition to new teaching practices (Fisher and Fraser 1991; Liu, Li, and Zou 2019; Loucks-Horsley et al. 2009; Patrick et al. 2010). The teachers in the present study felt that adapting to an active learning-focused class was a significant shift in teaching strategy that presented many time-consuming challenges, such as developing tasks and figuring out how to engage the students better consistently.

Another comment is that teachers who saw it as their responsibility to cover the curriculum in person found this more accessible by lecturing than by applying active learning formats. It is unclear whether the concerns about covering the curriculum and the time needed to do so are to be taken literally or whether this is to be understood as a need for support, as they have little or no training or background in active learning strategies. Regardless, guidance and support are likely highly desirable for the transition to the ALSs to take place.

The teachers employed several approaches to engage students, build positive relations with the students and develop good teaching strategies (see Section 3.1–3.3). Their strategy choices have already been identified and shown to be successful both in and outside of the ALSs for reducing student resistance to active learning and also categorised into either planning, explaining, or

facilitating for reducing student resistance toward active learning (Finelli and Borrego 2020; Johnson et al. 2021; Tharayil et al. 2018). All four teachers reported the need for time and support. However, none of the four were inclined to employ all the strategies and argued the importance of trial and error to explore and discover a teaching approach they felt suited them well. Failing to allow for this may increase teachers' social discomfort in transitioning to ALSs, and negatively influence their experiences with the ALSs. They all felt they had to both be good at and enjoy their chosen approach to be motivated to persist and build the desired student relations.

While the answers to research questions 1 and 2 are in accordance with existing literature findings, reaffirming these findings in a mathematical context and for Norwegian students has an independent value. Furthermore, it is essential to know the teachers' outlook on research questions 1 and 2 when evaluating the relationship between the challenges and their motivation, i.e. research question 3.

Self-reported social discomfort correlated with teachers' perception of ALSs as a more stressful environment, impeding the teachers' ability to build good student relations. Thus, for uncomfortable teachers, the ALSs may have the opposite effect of what was intended. The challenge of engaging students and building student relations was more difficult than expected for teachers with self-reported social discomfort. Where social discomfort is involved, teachers and others may underestimate the difficulty of transitioning to the ALSs. Indeed, if teachers that transition to ALSs underestimate the difficulty, they may experience a loss of motivation. Such a drop in motivation may, in turn, lead to reduced effort in transitioning to the ALS, as the task seems too challenging or less meaningful. Thus, while teachers must be motivated for the transition to occur, it is also vital that their motivations are based on realistic expectations. The results concerning research question 3 are novel and follow related reflections on professional development (Finelli, Richardson, and Daly 2013).

Furthermore, Cohen et al. (2019) found evidence that social anxiety in students was positively correlated with students' discomfort with the ALSs, which in turn negatively impacted students learning outcomes. It is plausible that teachers' comfort levels with the ALSs can influence students' comfort levels. If so, this adds an extra layer of importance in supporting teachers to be comfortable with active learning, ALSs, and the transition process.

The teachers reflected that good handling of one challenge positively influences success with the other challenges and vice versa. Thus, it becomes crucial to support teachers in overcoming all of the challenges they experience, as neglecting the challenge of one category can make the other categories appear needlessly challenging. It remains to be established how well teachers must overcome a particular challenge or set of challenges for their students to benefit from their ALSs classes. It is of interest to further study teachers that experience that they have overcome the significant challenges that come with the added affordances of teaching in the ALSs. Hopefully, such research will uncover more about best practices for active learning and the use of ALSs. In addition, while not the focus of this paper, it is still interesting to learn more about how subject matter and institutional strategy influence teachers. This topic warrants further studies and would be interesting to research across institutions with different strategies.

There are many alternatives to structuring significant challenges to overcome in the teaching and learning context, one example being the Community of Inquiry (Garrison et al., 1999). In line with Bernstein (2018), the research presented here is part of asking more profound questions related to the use of active learning and ALSs. Indeed, careful reflection on the context of active learning and ALSs is necessary to succeed.

Some of the teachers perceived the use of active learning and ALSs to be more difficult in mathematics than in other subjects. It has been established that active learning can improve student learning in mathematics (Freeman et al. 2014). While Rosenthal (1995) reflects that advanced mathematics does not easily lend itself to an energetic discussion, he proposes active learning strategies such as small group exercises to augment math classes. Indeed, Laursen and Rasmussen (2019) reflect that while inquiry learning in mathematics may seem distinct from inquiry learning in

science education, at the core, it is the same in mathematics. That active learning has been found to support good student outcomes in mathematics despite the high variety in instructor implementations speaks for the robustness of active learning in mathematics (Laursen et al. 2014). Furthermore, communication between students and teachers in constructive learning environments has been reported to foster better active learning in mathematics (McCartan, McNally, and Hermon 2011), and teachers commonly believe that traditional fixed-seat classrooms can hinder the use of active learning in STEM (Apkarian et al. 2021). Indeed, this supports the findings that active learning and ALSs work well, even in mathematics (Johnson et al. 2021). Finally, it becomes vital to reduce student resistance (Finelli et al. 2018) and offer professional development support to teachers, so they can challenge long-standing traditions on how to teach mathematics and transition to ALSs.

5. Conclusion

In this study, three categories of challenges for teachers attempting to adapt active learning approaches in an ALS have been identified and characterised by a combination of investigative and analytical approaches. The categories are 1) Engaging Students, 2) Building Student Relations, and 3) Developing Teaching Strategies.

The teachers felt it was necessary to handle all three categories well to benefit from the ALSs. If they struggled with one challenge, they also came to struggle with the others, negatively influencing their prospects of supporting the students' learning. However, the opposite was also true, succeeding in one aspect made it easier to overcome the other challenges. Mastering all three categories improved the teachers' motivation and created a positive cycle, beneficial to both teachers and students.

The teachers' success depended on their attitudes, motivation, and confidence. Belief in adapting active learning strategies or social discomfort being in the ALS was observed to have a crucial impact on the likelihood of adapting to student active learning.

To avoid potential downsides with the ALSs, the teachers should enter the ALSs with realistic expectations. Thus, informing teachers on challenges they may experience, and also supporting them in overcoming these challenges is central to the success of implementing student active learning in an ALS environment. For a widespread and efficient transition to active learning and ALSs, teachers must be afforded support according to their needs to change their practices and adopt new skills (Jones and Fevre 2021).

The author recommends that these findings are used to inform professional development towards supporting teachers who are new to ALSs. Such professional development may first inform about the challenges commonly encountered by teachers adapting to the ALS, secondly inform about tools that can be effectively used to overcome said challenges, and lastly inform the teachers on the dialectical relationship between how motivation and the challenges impact each other. Informing about the challenges can make teachers' expectations more realistic, make for a more fluid adaptation to ALSs, and prevent teachers from unexpectedly encountering these challenges so that they might abandon their transition to such spaces. Informing on the tools that can effectively be used may help teachers overcome the said challenges. Informing the teachers about the dialectical relationship between the challenges and their motivation may make the teachers more likely to maintain their motivation to use the ALSs and increase student learning outcomes by facilitating a good learning experience.

Beyond professional development, it is also of interest that the local institution changes towards a culture that motivates teachers to a higher degree to adopt and adapt effective teaching practices.

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Paper II

Comfort in Active Learning Spaces — Students' Perceptions and Preferences

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Manuscript submitted for publication.

Comfort in Active Learning Spaces –
Students' perceptions and preferences

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Keywords: Active, Learning spaces, Active learning, Students' perspectives, Students' perceptions, Higher Education

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Paper III

Mathematics in Active Learning Spaces

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Manuscript submitted for publication.

Mathematics in Active Learning Spaces

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Keywords: Active, Mathematics, Learning spaces, Active learning, Teachers' perspectives, Higher Education

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