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Pedagogical Approaches to Enhancing Student Self-Efficacy and Addressing Gender Inequality in Undergraduate STEM

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Pedagogical Approaches to Enhancing Student Self-Efficacy and Addressing Gender Inequality in Undergraduate STEM

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by

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ABSTRACT

Previous research has shown that the success and retention of students in STEM university programmes are highly correlated with their self-efficacy beliefs, and women and gender minority students in STEM have been consistently found to possess lower self-efficacy than men. Since specific teaching and learning practices are known to contribute to increased self-efficacy and help diversify STEM education, this study sought to identify which pedagogical approaches are effective in creating a more equitable learning environment in introductory STEM classes by positively contributing to students' self-efficacy. This study employed methodological triangulation and synthesised findings from self-efficacy questionnaires, classroom observations, and a focus group interview. Statistically significant effects on self-efficacy were identified based on student profile (gender, study field, and previous performance) and class setting (class size and instruction week). Examination of the teaching and learning practices in the observed classes revealed that didactic teaching methods were linked to a higher prevalence of students with low confidence levels, both within lectures and practical classes, although this tendency was less pronounced in the case of lectures. Subsequent investigation through a Classification and Regression Tree (CRT) analysis of teaching and learning activities within the lecture context indicated that optimal time management and engagement in active learning exercises were the best predictors of higher levels of student confidence. The focus group interview with female and gender minority students identified positive class atmosphere, student-staff relationships, and teaching and assessment practices that prioritise student comfort and provide students with ample knowledge application and achievement opportunities as the main factors contributing to their confidence positively. Implications for instruction are discussed.

DECLARATION

I certify that this thesis which I now submit for examination for the award of MPhil, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for graduate study by research of the Technological University Dublin and has not been submitted in whole or in part for another award in any other third-level institution.

The work reported in this thesis conforms to TU Dublin's principles and requirements for ethics in research.

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Signature: Gintarė Lübeck   Date: 31.01.2023

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ABBREVIATIONS LIST

COPUS – the Classroom Observation Protocol for Undergraduate STEM

CRT – classification and regression trees

GM – gender minority

LC – Leaving Certificate

M – median

SD – standard deviation

SE – self-efficacy

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INTRODUCTION

1.1 RESEARCH CONTEXT AND RATIONALE

Self-beliefs hold significant sway over peoples' academic decisions, achievements, and career trajectories (Bandura, 1997). However, these beliefs are subject to the impact of numerous external factors, with gender inequality occupying a prominent position among them (Bussey & Bandura, 1999). Gender inequality in higher education manifests across various domains, encompassing recruitment and promotion processes, funding allocation, authorship opportunities, workload distribution, organisational values, and the prevailing scholarly culture (Drew & Canavan, 2020). The existence of persistent barriers within academia creates challenges for women, influencing their perceptions of competence and suitability for academic careers, and contributing to the phenomenon commonly referred to as the "leaky ladder" in higher education (Royal Society of Chemistry, 2018; UNESCO, 2017). Likewise, gender minority students encounter distinct obstacles throughout their academic journeys, which can detrimentally affect their self-perceptions, impede their educational outcomes (Wilkinson et al., 2021), and discourage engagement with STEM fields (Xavier Hall et al., 2022). Consequently, the enduring underrepresentation of both female and gender minority students within STEM university programmes remains a pressing concern (European Commission, 2021; Xavier Hall et al., 2022).

The 2030 Agenda for Sustainable Development outlines 17 Sustainable Development Goals, among which are inclusive and equitable quality education at all levels (Sustainable Development Goal 4), gender equality (Sustainable Development Goal 5), reduced inequalities (Sustainable Development Goal 10), and effective, accountable, and inclusive institutions (Sustainable Development Goal 16). The Second National Strategy on Education for Sustainable Development - ESD to 2030 (Government of Ireland, 2022) lists social justice, equity, and inclusion among its key principles. While Ireland has seen a lot of positive change regarding the educational attainment of women (Government of Ireland, 2017), based on 2018 statistics by the European Commission (2021), gender disparities in STEM fields are still observable at every level of higher education. At the level of undergraduate study, graduation rates for female students in the fields of natural sciences, mathematics, statistics, and engineering are lower than for men. Women are also less likely to proceed to doctoral studies after graduating from their master's studies in STEM fields. At the doctoral level, while women are well represented in biological and environmental sciences, they remain underrepresented in physical sciences, mathematics and statistics, information and communication technologies, and engineering. Although a lot has been achieved over recent years, Ireland still has a long way to go before gender parity in higher education is reached. In order to ensure continuous implementation of the Sustainable Development Goals while striving for gender equality, officeholders highlight the need to continue monitoring educational policies and practices across all levels of education (Harris, 2022, June 16).

To account for the prevalence of the gender gap, confidence beliefs of women in STEM and their relationship to STEM aspiration have been thoroughly researched. Studies show that self-efficacy strongly influences the selection of study subjects (Moakler Jr & Kim, 2014; van Aalderen-Smeets & Walma van der Molen, 2018) and that self-efficacious students perform better, display higher motivation, and are more likely to persist in their academic careers (Klassen & Usher, 2010). The fact that women in STEM have been consistently found to possess lower levels of self-efficacy than men (Dalgety & Coll, 2006; Lindstrøm & Sharma, 2011; Pajares & Miller, 1994) is a serious concern. In order to finally bridge the gender gap in STEM subjects, solutions to help improve the self-efficacy beliefs of female and gender minority students are needed. Seeing how the ratio of Bachelor graduates to Bachelor entrants in STEM programmes in Ireland is higher for men, interventions to help prevent attrition of non-male students in STEM need to be introduced at the undergraduate level.

1.2 RESEARCH AIM AND OBJECTIVES

Since specific teaching and learning practices are known to affect self-efficacy levels of STEM students (Bailey et al., 2017; Dunlap, 2005) and help diversity in STEM courses (Ballen, Wieman, et al., 2017; MacPhee et al., 2013), this study sought to identify which pedagogical approaches currently employed at a large modern research university contribute the self-reported self-efficacy of undergraduate students and indicate how female and gender minority students in STEM can continue to be consciously supported through pedagogical practice in the future. In order to understand how self-efficacy beliefs of undergraduate female and gender minority STEM students are affected by teaching practice, this study was guided by two inquiries.

Firstly, this study sought to explore the existing self-efficacy beliefs among undergraduate STEM students and reveal patterns among student groups, depending on a variety of demographic factors (gender, age, ethnicity, generational status), study field, and prior performance. Women and gender minorities tend to be more susceptible to biased self-perception on the basis of gender stereotypes (Bussey & Bandura, 1999), which are often perpetuated by a lack of role models (Cotner et al., 2011), unavailability of support (Lester, 2010), and gender discrimination (Moss-Racusin et al., 2012) in the STEM disciplines. Therefore, a lower science self-efficacy score was expected among female and gender minority students. Even lower self-efficacy scores were anticipated among women in study fields where gender distribution is the most unbalanced, and among women and gender minority students belonging to double and multiple-minority groups.

Secondly, this study sought to establish which teaching practices are the most efficient in developing strong self-efficacy beliefs among all STEM students, and women and gender minority STEM students, in particular. Prior research has identified student-centred, collaborative pedagogical practices as most beneficial to the development of student confidence (Bailey et al., 2017; Carpi et al., 2017), and thus, STEM courses which utilised multiple and diverse student-centred instructional practices were expected to have higher average self-efficacy and receive more positive student feedback. This study compared data collected from self-efficacy questionnaires, observations of classes in a variety of STEM modules, and a focus group interview to answer the research questions.

2. LITERATURE REVIEW

2.1 SELF-EFFICACY

The concept of personal efficacy was first introduced by Albert Bandura in 1977 as part of his social learning theory. He defined efficacy expectations as beliefs about whether "one can successfully execute the behavior required to produce the outcomes" (Bandura, 1977b, p. 79). In his later works, self-efficacy has been described as confidence in one's capability to utilise the skills one possesses to successfully perform a certain task within a given context (Bandura, 1986, 1997). Self-efficacy directly influences personal aspirations and the motivation to pursue them, thereby exerting an impact on academic and professional goals (Bandura, 1986). Self-efficacy beliefs have also been linked to motivation and persistence in achieving goals, perseverance when faced with obstacles, and resilience to mental distress (Bandura, 1977a; Bandura et al., 1996). Therefore, self-efficacy is a central concept when researching ways to support the academic performance and retention of student groups who have been found to underperform in STEM contexts.

Not only do self-efficacy beliefs affect how people react to encountering obstacles or experiencing failure, but they also decide what deficient performance or failure is attributed to. The attributions of success and failure are usually impacted by convictions about the influence of ability, expended effort, task difficulty, and luck on results achieved (Bandura, 1997). When success is attributed to ability, self-efficacy is enhanced, whereas attributions to luck or effort tend to diminish it. Furthermore, self-efficacious individuals tend to attribute failure to contextual factors like lack of effort, while those with low self-efficacy are more inclined to attribute failures to a lack of inherent ability (Bandura, 1997). In the context of STEM education this attribution pattern directly affects students' perseverance as students who attribute their failures to an innate lack of ability may experience a decline in their sense of belonging (LaCosse et al., 2016) and contemplate switching subjects or leaving their university programmes following setbacks (Nauta et al., 1999), convinced that they lack the necessary qualities to succeed in their chosen field.

2.2 SOURCES OF SELF-EFFICACY BELIEFS

Self-efficacy influences multiple areas of academic functioning, including domain selection, intentionality to continue academic education, and academic performance. Self-efficacy beliefs have received particular attention in STEM fields, given the ever-increasing demand for STEM professionals and the high attrition rates among students in STEM programmes. In order to devise effective self-efficacy interventions in STEM disciplines, it is vital to understand how self-efficacy beliefs are formed.

There are four main sources of self-efficacy beliefs: performance accomplishments, vicarious experience, verbal persuasion, and physiological states (Bandura, 1977a, 1977b, 1986). Each self-efficacy source affects academic self-efficacy differently. While a lot of research has been dedicated to establishing which sources of self-efficacy information are the strongest influencers of overall self-efficacy, or which have the strongest predictive value over specific variables, each source of self-efficacy beliefs makes a unique contribution to student confidence and no single source can give the full picture (Sheu et al., 2018). Additionally, students may rely on different sources of self-efficacy beliefs depending on their demographic characteristics and academic profile. Therefore, all four sources of self-efficacy information, and the interplay between, must be carefully investigated.

2.2.1 Performance Accomplishments

Self-efficacy beliefs stemming from performance accomplishments (or mastery experiences[1]) are based on personal experiences regarding the execution of tasks within a specific domain. While previous successes in the domain increase the strength of self-efficacy beliefs, previous failures undermine confidence in capabilities, especially if they had occurred repeatedly or irrespectively of the effort invested and in otherwise favourable circumstances (Bandura, 1986, 1997).

Performance accomplishments are often considered the most reliable source of self-efficacy information as information extracted from past performance is often perceived as the most genuine when validating capabilities (Bandura, 1997). Britner and Pajares (2006) found that mastery experiences was the only source of self-efficacy beliefs to significantly predict science self-efficacy among middle school students. The same trend has been observed in

[1] The terms *performance accomplishments* and *mastery experiences* describe the same concept and are used interchangeably in the literature as well as within this thesis.

mathematics education as well. In a study with high school students, Lopez and Lent (1992) found that performance accomplishments (in regard to both actual and perceived performance) had the strongest influence over mathematics self-efficacy. At university level, a study with psychology students in an introductory psychology class produced similar results with both actual performance and perceived performance being the biggest contributors to mathematics self-efficacy beliefs (Lent et al., 1991). Hackett (1985) found that prior mathematics experience (years of secondary mathematics education) and achievement (mathematics scale scores from the American College Test) were highly correlated with math self-efficacy, although math anxiety also played a central role in shaping students' self-efficacy beliefs. A study by Zeldin and colleagues (2008) identified performance attainments as the main source of self-efficacy information and motivation behind the decision to pursue STEM careers among male students from a variety of STEM disciplines.

In undergraduate science, the influence of prior academic experience on student self-efficacy is much more ambiguous. Students in the early stages of STEM education have little experience within their discipline and, for some of them, prior instruction in related school subjects is an important contributor to their self-efficacy beliefs. Prior instruction in related school subjects has been found to be predictive of self-efficacy in introductory university courses in psychology (Hackett, 1985), chemistry (Dalgety & Coll, 2006), biology (Ainscough et al., 2016), and physics (Kalender et al., 2020). In addition, prior achievement in the subject is often indicative of how self-efficacious students are in their university courses and students who performed well in certain subjects in secondary school are likely to have higher academic self-efficacy for related university courses (Ainscough et al., 2016).

However, there are cases where the secondary school experience seems to have no direct correlation with student self-efficacy in introductory science courses. Intriguing findings arise when comparing students with prior experience to those without any previous instruction in the field. Lindstrøm & Sharma (2011) discovered that male students without prior physics instruction reported the highest levels of self-efficacy in an introductory physics course when compared to female students with no prior instruction, female students with prior instruction, and male students with prior instruction. As the authors suggested, this could be explained by the high likelihood of inaccurate self-appraisals before experiencing “any significant formal instruction in physics, which is the case in week 3 of first semester” (p. 14). As students accumulate more experience in their field of study, their self-efficacy beliefs are increasingly influenced by the course experience itself. This was true for the male students without prior physics instruction, who adjusted their self-perceptions by the end of the first semester, leading to a significant decline in confidence levels (Lindstrøm & Sharma, 2011). A similar trend, where course experience rather than prior experience informs student self-efficacy as the course progresses, was observed in the study by Ainscough and colleagues (2016). By the end of the semester, high school biology and chemistry no longer accounted for any variation in self-efficacy scores among first-year biology students, with progressive grade emerging as a significant predictor instead (Ainscough et al., 2016).

Other interesting discrepancies between previous experience and student self-efficacy can sometimes be observed based on student profiles. As people gain more knowledge and experience within a certain domain, their domain-specific self-efficacy is expected to increase as well. Indeed, undergraduate students’ self-efficacy was found to improve during the first year of their university programme in both quantitative study courses and humanities (Han et al., 2021). Nevertheless, studies measuring self-efficacy throughout the first semester in undergraduate programmes find that while self-efficacy scores increase by the end of the semester on average, students who report lower self-efficacy at the beginning of the semester also report lower self-efficacy at the end of the semester (Ainscough et al., 2016; Moreno et al., 2021). While this could indicate that students with lower self-efficacy performed worse and thus maintained lower self-efficacy with regard to their peers despite gaining new skills and experience, the persistent self-efficacy discrepancies are most often observed among those underrepresented in STEM, often regardless of their achievement level (Marshman et al., 2018).

Different conditions under which performance achievements are acquired have an effect on personal self-efficacy as well. Three main factors are known to affect how self-efficacy information from mastery experiences is internalised: (1) malleability of personal capability, (2) existing self-perception, and (3) circumstances under which a task is performed (Bandura, 1997). Those who believe in the unchanging nature of capability tend to interpret successful achievements as being the result of hard work and are less likely to persevere in their endeavours (Bandura, 1997). This is in line with previous research on incremental and entity ability beliefs. According to Dweck (1999) and Dweck and Leggett (1988), those who possess incremental beliefs about the nature of ability, namely believe that ability is changing and can evolve with time and effort, are more persistent in their academic pursuits and strive to improve their ability. On the contrary, those who hold entity beliefs about the nature of ability, and perceive ability as permanent and not alterable, are only performance-oriented in that they seek to prove their ability, and when perceived ability is low, try and avoid challenges as they may prove discrediting. Pre-existing self-beliefs also influence how new self-efficacy information is organised since instead of evaluating their performance objectively, people tend to assess how well it fits in with their preformed perceptions of themselves. Performances that are perceived as inconsistent with self-efficacy beliefs are frequently disregarded and provide less informative feedback for future self-efficacy. On the other hand, performances that align with existing self-perceptions tend to reinforce and strengthen one's self-efficacy beliefs. The conditions under which the task is executed have an effect over how self-efficacy is acquired from mastery experiences in that they help contextualise one's performance. Such factors as perceived task difficulty, the amount of effort and support required to successfully accomplish the task as well as the environment in which the task was executed (optimal vs suboptimal) help determine to what extent new self-efficacy information will affect capability beliefs.

A recent meta-analysis by Sheu et al. (2018) placed particular emphasis on how mastery experience is assessed and claimed that "how people encode, weigh, and recall their performances can often have a greater impact on self-efficacy beliefs than does the objective success or failure of a single past performance" (p. 132). How self-efficacy information from past accomplishments is interpreted, and the extent to which it is internalised, depends on a variety of individual variables and is highly subjective. Therefore, although performance accomplishments are of undeniable importance in gaining confidence generally, their exact influence on self-efficacy differs significantly depending on the unique educational setting and student characteristics (Sheu et al., 2018).

2.2.2 Vicarious Experience

Self-efficacy can also be influenced through comparisons to similar others. Performing better than others in the same conditions or at the same tasks increases self-efficacy, while performing below group norms results in lower self-efficacy beliefs (Bandura, 1997). The extent to which self-efficacy is influenced through vicarious experience depends on the perceived similarity between the observer and the observed. Seeing people with a similar predisposition succeed in a specific domain improves self-efficacy while seeing them fail reinforces the idea of domain-specific goals being unachievable (Bandura, 1986). Bandura (1997) noted that, generally, vicarious experience has a weaker influence on self-efficacy than direct experiences. A meta-analysis by Sheu et al. (2018) revealed that although all components of self-efficacy significantly contributed to overall self-efficacy, the effect size for vicarious learning was medium, while all other sources had a strong effect size. Nevertheless, vicarious experience plays an important role in mediating the impact of self-efficacy information obtained from direct experience and, in certain circumstances and for certain individuals, vicarious experience can be more important than any other sources of self-efficacy.

When considered individually, vicarious experience can be instrumental to self-efficacy beliefs in situations where direct experience is lacking. Vicarious learning can strongly influence a person's confidence when they have not yet been exposed to enough opportunities for mastery experiences and have a limited ability to self-evaluate due to lack of experience. Self-efficacy information obtained from vicarious experience is also especially influential when it differs from the self-efficacy information obtained from previous performance achievements. People with prior experience of success will behave less effectually when observing those similar to them fail in the same domain while seeing similar others perform well will bolster efforts and improve perseverance in spite of past failures (Bandura, 1986).

Vicarious information has proved especially important in helping develop and sustain the academic self-efficacy of underrepresented groups. For instance, Zeldin and Pajares (2000) found that for women in male-dominated university programmes and careers, vicarious experience was one of the most important sources of self-efficacy information. According to Bandura (1997), people actively seek out models in their environment who they look up to. Indeed, in Zeldin and Pajares' study, women reported being inspired to persevere in their domains, especially during a time of difficulty, by positive role models in their familial, social, academic, and professional circles. Having family members with careers in scientific fields and being exposed to math and science skills in their home environment, having high-achieving friends and being part of a science club or community, and having teachers and supervisors who are obviously enthusiastic about their field helped them bolster their confidence in their own capability in science and influenced their convictions about women in scientific fields.

Conversely, vicarious learning has also been found to negatively relate to self-efficacy beliefs of female and racial/ethnic minority students in STEM fields. When analysing the correlations between direct experiences (performance accomplishments, verbal persuasion, and physiological states) and vicarious learning, Sheu et al. (2018) discovered important differences in how they influence self-efficacy based on gender and race/ethnicity, revealing a stronger negative vicarious learning to self-efficacy path for female and racial/ethnic minority students. Although Sheu and colleagues (2018) note that the negative path could be induced by statistical suppression, the variation of the suppression effect by gender and racial/ethnic group poses interesting implications. Sheu and colleagues (2018) acknowledge that this variation might be due to a possibility that marginalised and underrepresented groups are exposed to more adversity and prejudice, which has a "dampening effect" (p. 131) on their self-efficacy.

In education, the concept of modelling (Bandura, 1997) is vital to the intentional formation of student self-efficacy beliefs through vicarious experience. Modelling instruction facilitates observational learning in which students are provided with "a clear image of how a skill should be performed" (Zimmerman & Kitsantas, 2002, p. 660). Modelling is a hugely effective pedagogical practice since it provides an easy-to-follow, step-by-step approach to the problem at hand. It exposes people to activities and situations they are anxious and insecure about, thus increasing their knowledge about those situations and improving predictability and preparedness, which in turn, reduces anxiety (Bandura, 1997). It also provides students with viable coping strategies and solutions to difficulties they are likely to encounter, thus improving perceived control over the situation.

Observational learning is especially helpful in unfamiliar areas and when acquiring new skills, since it equips students with fundamental knowledge on how a task should be executed and prepares them to attempt executing the task on their own (Zimmerman & Kitsantas, 2002). This makes modelling instruction a very impactful teaching practice in undergraduate education. However, the success of modelling as a teaching practice highly depends on whether the person perceiving the model sees themselves as similar or different from the model. Dissimilarities with the model will undermine modelling, while similarities will increase its effects (Bandura, 1997). Therefore, similarities between the students and the model are important to establish on the following levels: age, gender, academic level, socioeconomic status, race, and ethnicity (Bandura, 1997). A study by Adams (2004) discovered that when trying to improve the self-efficacy beliefs of international postgraduate students in STEM fields towards research seminar presentations, students' self-efficacy beliefs increased only when being exposed to a peer model (in this case a non-native English-speaking international student) while using a senior academic as a model for successful oral presentations proved statistically non-significant for improving academic public speaking self-efficacy. Similarly, previous studies in the field of engineering have shown that students who interacted with computer models of the same gender (Rosenberg-Kima et al., 2008) and race (Rosenberg-Kima et al., 2010) were able to discount negative engineering stereotypes and reacted more positively towards engineering. Other studies, however, show that a significant relationship to the model is more important than biographical similarity, with women reporting being strongly influenced by positive male role models (Zeldin & Pajares, 2000). Regardless, exposing students to as many, and as diverse, models as possible will create the best opportunities to increase self-efficacy through vicarious experiences (Bandura, 1997).

2.2.3 Verbal Persuasion

As a source of self-efficacy beliefs, verbal persuasion operates through social encouragement and support. Verbally persuading someone to believe that they can be successful at a given task can act as an incentive to increase efforts for those that are reasonably likely to succeed. However, situations in which the receiver of verbal encouragement fails at an attempted task can result in the discreditation of social persuasion as a valid source of self-efficacy beliefs and have a lasting negative effect on self-efficacy (Bandura, 1997). While positive verbal messages have a varying influence on people, receiving verbal discouragement is highly likely to cease one’s efforts towards a certain goal (Bandura, 1986).

In education, self-efficacy information in the form of verbal persuasion is often transmitted through evaluative feedback on performance. However, not all feedback affects the development of self-efficacy in the same way. Feedback regarding successes that emphasises capability and effort is known to raise self-efficacy (Bandura, 1997) while emphasising ability in achieving success (Nauta et al., 1999) and blaming failure on the lack of individual initiative and effort (Bailey et al., 2017) harms self-efficacy beliefs.

The effectiveness of social messages in influencing self-efficacy is mediated by three fundamental factors (Bandura, 1997). Firstly, the extent to which self-efficacy information from verbal persuasions is internalised is reliant on the perceived credibility of the source of verbal persuasion. In the context of higher education, both feedback from successful peers and instructors has been shown to significantly affect student self-efficacy (Bailey et al., 2017) and result in similar increases in performance (Huisman et al., 2019). Secondly, the impact of verbal persuasions on self-efficacy is mediated by the strength of personal conviction in own ability; those that are more confident in their self-appraisal than the opinion of others are more likely to be unaffected by verbal persuasion. Thirdly, verbal persuasion is most effective in influencing self-efficacy beliefs when combined with other, seemingly more objective sources of self-efficacy information, such as performance achievements. Therefore, pedagogies that seek to positively influence self-efficacy beliefs should not only provide students with positive feedback but also create ample opportunities for personal success (Bailey et al., 2017a; Carpi et al., 2017).

Not unlike vicarious experience, verbal persuasion as a source of self-efficacy information appears to be more important to women (Lindstrøm & Sharma, 2011; Schunk & Lilly, 1984; Zeldin & Pajares, 2000) and ethnic minorities (Zeldin et al., 2008). Zeldin and Pajares (2000) found that alongside vicarious experience, verbal persuasion plays an important role in domain selection and retention for women in mathematical, scientific, and technological careers. Similarly, gendered social messages from family members, teachers, and especially peers, have been identified as a significant influence in the academic paths of women, contributing to low numbers of women selecting science and engineering courses, and low levels of academic self-efficacy and commitment among female science and engineering students (Leslie et al., 1998). This is analogous to a more recent study by Marshman and colleagues (2018), which identified that in physics university courses, stereotypes as social messages can often be a source of negative self-efficacy information and influence interest and career decisions, as well as contribute to inaccurate attributions of success.

2.2.4 Physiological States

The development of self-efficacy beliefs may also be subject to influence from physiological states. Anxiety and stress, in particular, are known to lower perceived self-efficacy both directly and by undermining the ability to effectively perform in a specific situation (Bandura, 1997). To some extent, everybody experiences physical and emotional distress when under pressure; however, the perception and interpretation of physiological states have an important effect on self-efficacy beliefs. Self-efficacious people tend to see physiological states as natural responses to high-stake situations, while people with low self-efficacy might interpret nervousness as personal inadequacy, thus creating negative performance experiences that further inform self-efficacy beliefs (Bandura, 1986).

States of mind play an important role in gaining self-efficacy information in achievement situations as well (Bandura, 1997). Attitude affects perceived self-efficacy in achievement situations, with successes achieved while in a positive mindset resulting in the highest gains in self-efficacy, and failures experienced while in a negative mindset resulting in the highest losses in confidence regarding capability (Bandura, 1997). Additionally, a positive attitude can activate memories of past accomplishments, thus setting one out for success, while a negative attitude can bring up memories of past failures and have a hindering effect on performance (Bandura, 1986).

The relationship between physiological states and self-efficacy is reciprocal. In an educational context, physiological states caused by low self-efficacy have been found to negatively affect performance and attitude towards science, especially in first-year STEM contexts. For example, Kurbanoglu (2014) found that low self-efficacy among first-year chemistry students predicted laboratory anxiety and negatively influenced their attitudes towards chemistry. In addition, anxiety experienced in the context of first-year university education has been found to negatively affect performance in undergraduate biology (Ballen, Salehi, et al., 2017; England et al., 2017) and physics (Malespina & Singh, 2022).

While anxiety is very common among all undergraduate science students, it is especially common among women and gender minority students. Gender minority students are generally more susceptible to mental health issues than their gender-majority peers (Chew et al., 2020; Lawrence & McKendry, 2019), while women have been found to exhibit higher anxiety levels towards science than men (Mallow, 1994) and to be more prone to experience unpleasant affective states in relation to direct learning experiences than men in STEM (Sheu et al., 2018). Due to the reciprocal relationship between self-efficacy and physiological states, STEM students with low self-efficacy are more susceptible to physiological states in performance situations. For example, in introductory physics, Melespina & Singh (2022) found that self-efficacy played a mediating role on female students' performance in high-stake assessments and examinations, with lower self-efficacy and higher test anxiety among female students resulting in lower scores. However, the study revealed no difference in performance in lower-stake assessment situations, where students are likely to experience lower levels of stress. Similar findings were presented in the context of introductory biology, where women performed worse than men in exams but better than men in other modes of assessment (Ballen, Salehi, et al., 2017). Other groups underrepresented in STEM, such as mature students (Jameson & Fusco, 2014) and first-generation students (Hood et al., 2020), are also known to be subject to higher levels of anxiety. Therefore, self-efficacy interventions targeting physiological states might be of particular importance when addressing inequalities in STEM education.

The previous subsections showcase that each of the four sources of self-efficacy information is highly context and individual-dependent. Although mastery experiences were originally thought to have the strongest influence on self-efficacy beliefs, recent findings show that "the four sources may tend to converge on a coherent story regarding one's capabilities at STEM pursuits" (Sheu et al., 2018, p. 132). Ultimately, the more sources of self-efficacy students are exposed to, and the more consistent the information acquired from each source is, the more chance there is that students will develop a robust sense of personal self-efficacy (Bandura, 1997).

1.3 SELF-EFFICACY AND ACADEMIC FUNCTIONING

Correlations between academic self-efficacy and various dimensions of academic functioning have been thoroughly researched. Beliefs students hold about themselves have been found to affect their interest in and preferences towards certain academic and professional domains, perceived career opportunities, ambition, and resilience to encountered obstacles, as well as academic attainment. The following sub-sections provide a detailed overview of the main findings.

2.1.1 Choice of Domain

In relation to career, higher self-efficacy beliefs are linked to a wider range of considered options, while lower self-efficacy beliefs lead to an exclusion of certain fields and professions (Bandura, 1997; Bandura et al., 1996) and hinder academic career progression (Kinahan et al., 2021). Additionally, domain-specific self-efficacy is highly correlated with career decisions. General STEM self-efficacy is connected to the selection of STEM degree programmes (Fencl & Scheel, 2005; van Aalderen-Smeets et al., 2019) and intentionality to continue STEM education (Bong, 2001; Carpi et al., 2017).

Previous research has identified a variety of factors capable of predicting academic and occupational choices. For instance, creative interest and extroversion have been found to negatively relate to the choice of mathematics and science university majors (Lapan et al., 1996). More years of secondary mathematics instruction (Hackett & Betz, 1989), previous performance (Moakler Jr & Kim, 2014), interest in mathematics and outcome expectations (Lent et al., 1991; Lent et al., 1993), and ability beliefs (van Aalderen-Smeets et al., 2019) have been found to play a significant role as well. However, the latter variables are often interconnected with self-efficacy beliefs. For example, the relationship between interest and career decisions is largely affected by self-efficacy beliefs in that self-efficacy "mediates the effects of prior performance on interest, and interest, in turn, mediates the effects of self-efficacy on career aspirations" (Lent et al., 1991, p. 429).

What is more, self-efficacy has consistently been indicated as having the largest influence over career and academic decisions. Bandura (1997) argued that domain self-efficacy was the strongest predictor of domain choice and contributed more to educational and career decisions than the amount of previous instruction, ability level, and prior achievement. This has been reflected in mathematics-related major choices (Hackett & Betz, 1989). Several studies researching pedagogical approaches to STEM education found that increasing students' self-efficacy via problem-based learning (Dunlap, 2005), active and cooperative learning (Felder et al., 1998), and undergraduate research (Carpi et al., 2017) can result in improved career ambition, resilience, and retention of STEM students.

A number of sociocultural factors are known to affect academic choices through self-efficacy. Higher socioeconomic status and familiarity with a STEM environment can increase student confidence for STEM fields. For instance, a study by Moakler Jr and Kim (2014) revealed that students who had parents with STEM professions were 1.6 times more likely to choose a STEM degree. On the other hand, negative stereotypes and lack of representation in STEM disciplines have been found to have a negative impact on career choices among underrepresented groups.

Some studies show that while men's self-efficacy beliefs are similar in both female and male-dominated disciplines, women tend to display a much lower sense of self-efficacy for male-dominated academic domains and professions and higher self-efficacy for gender-typical professions (Betz & Hackett, 1981). Other studies reveal that gender-based stereotypes affect both men and women. For instance, a study by Han and associates (2021) found that in their first year of university, men tend to have lower self-efficacy in humanities while women have lower self-efficacy in STEM subjects and that this pattern is maintained over time, despite general increases in self-efficacy for both genders. Pervasive societal stereotypes about suitability for certain careers are often used to explain gender distribution in STEM disciplines where the gender gap is the largest, such as engineering (Rosenberg-Kima et al., 2008), or physics (Kalender et al., 2020).

Additionally, negative social messages are known to contribute to the lack of ethnic diversity in STEM and the high dropout rates of ethnic minority students. Greaves et al. (2022) found that lack of representation, role models, and career opportunities in STEM were some of the common reasons for persisting ethnic disparities in academia. Similar discoveries were made by Concannon & Barrow (2009), who reported the perceived inability to realise their full potential and unequal opportunities due to racial discrimination as the main cause of low career self-efficacy among black students in engineering.

While increasing intentionality to study STEM subjects among groups underrepresented in STEM is a vital step in improving the diversity of STEM university programmes, it is equally important to ensure that students from underrepresented groups who have decided to pursue STEM degrees are retained. Groups traditionally underrepresented in STEM are known to be at a higher risk of not completing their study programmes, changing their major, or choosing not to continue STEM education past graduation (Nauta et al., 1999). Therefore, the role of self-efficacy in influencing student motivation and commitment to STEM education needs to be carefully examined.

2.3.2 Motivation and Persistence

Self-efficacy influences the ability to cope in the face of challenges (Bandura, 1977). When applied to STEM education, self-efficacy is known to affect motivation, effort expenditure, and persistence (Klassen & Usher, 2010) as well as intentionality to continue academic education (Bong, 2001).

A strong sense of personal efficacy is instrumental when trying to improve diversity at university level. Since low self-efficacy often results in avoidance of potentially challenging situations, low academic self-efficacy often leads to increased attrition from university programmes. Self-efficacy is particularly important for the retention of groups underrepresented in STEM (Kalender et al., 2017; MacPhee et al., 2013; Zeldin & Pajares, 2000) since students with a strong sense of self-efficacy are able to see hurdles in their STEM careers as challenges that can be overcome and invest more effort into achieving their goals, especially under difficult conditions (Bandura, 1986; Lent et al., 1994; Zeldin et al., 2008).

While persevering in the face of challenges can help increase confidence and eradicate defensive behaviour, quitting on challenging tasks results in increased anxiety and lower belief in capability and may lead to a student's decision to prematurely abandon their academic pursuits (Bandura, 1977). Therefore, pedagogies that create multiple low-stake opportunities to achieve help increase self-efficacy and improve retention, while anxiety-inducing pedagogies and evaluation practices lower student confidence and motivation to persist and increase chances of student attrition. Anxiety inducing evaluation practices have been found to especially disadvantage women in science (Ballen, Salehi, et al., 2017; Malespina & Singh, 2022), while active learning can prove especially stressful for students in large enrolment science courses (Cooper et al., 2018), first-generation students (Hood et al., 2020), and students with higher general anxiety (England et al., 2017).

Previous research has shown that self-efficacy has an important influence over motivation and persistence in mathematics education (Hackett & Betz, 1989; Randhawa et al., 1993), proficiency in which is vital for the selection of a variety of scientific degrees and occupations, and higher self-efficacy has consistently been linked to stronger persistence in a variety of STEM fields (Ainscough et al., 2016; Lent et al., 1984; Nauta et al., 1999). Self-efficacious students have been found to set higher goals for themselves (Zimmerman et al., 1992), be more learning-focused and engage in more effective learning practices by using deep-level cognitive processing strategies (Anderman & Young, 1994), exhibit self-enhancing behaviour, recover from failure easier and be more motivated by academic success (Zander et al., 2020), as well as have better coping strategies and experience anxiety less (Kalender et al., 2020). Due to the contribution of self-efficacy to STEM motivation and intentionality to persist in science, self-efficacy interventions (discussed in more detail in section 2.5) have been suggested to help increase retention and graduation rates.

2.3.3 Performance and Achievement

As discussed in subsection 2.2.1, the relationship between self-efficacy and performance is reciprocal: positive performance feedback[2] can reinforce students' confidence in their capabilities, while high-self efficacy is known to enhance performance. Self-efficacy beliefs regarding a particular task are predictive of the actual capability to execute that task as well as of how people feel about themselves performing the task and their attitudes to the task itself (Pajares & Miller, 1994). This is fundamental to students' perceived suitability for specific domains and can inform their wider academic and occupational decisions. Therefore, due to their role in improving performance, self-efficacy interventions are of particular importance to student groups that are low-achieving or that belong to marginalised groups that traditionally suffer from lower academic self-efficacy and display a higher reliance on positive performance feedback.

Researchers have reported self-efficacy beliefs to relate to academic achievement both in secondary (Randhawa et al., 1993; Williams, 1994; Zimmerman et al., 1992) and tertiary education (Bong, 2001; Ramos-Sánchez & Nichols, 2007). Correlations between self-efficacy and achievement have been reported in general STEM contexts (Lent et al., 1984;

[2] The term *performance feedback* used here encompasses various indicators of performance, such as grades or marks.

MacPhee et al., 2013) as well as specifically in chemistry (Moreno et al., 2021; Villafañe et al., 2016), astronomy (Bailey et al., 2017), physics (Fencl & Scheel, 2005; Kalender et al., 2020), and engineering courses (Hackett et al., 1992; Mamaril et al., 2016). As research has shown, self-efficacy plays an important role in increasing students' chances of executing course tasks and progressing through their study programme successfully, thus helping them achieve their academic goals.

While several factors are known to influence academic self-efficacy in STEM fields, such as years of prior instruction or prior achievement, self-efficacy might be speculated to merely mediate the effect of those factors when predicting performance. However, multiple studies reveal that self-efficacy can predict achievement better than other determinants. For instance, Zimmerman and colleagues (1992) identified self-efficacy for academic achievement as the strongest predictor of academic performance among secondary school students and found that self-efficacy influences academic achievement both directly and by affecting personal goals. Interestingly, while Zimmerman and colleagues identified that students' prior grades correlated with their academic self-efficacy, they found that the direct path of influence between students' prior and final marks was non-significant, revealing that self-efficacy has a unique predictive power over achievement. At university level, Pajares and Miller (1994) observed that mathematics performance, specifically problem-solving ability, is also best predicted by students' self-efficacy beliefs. They found that other variables, such as prior experience and gender, influenced performance only through their influence on self-efficacy and that self-efficacy had the strongest direct effects on performance. Similarly, Lent and associates (1984) identified that self-efficacy was the best predictor of performance in technical and scientific subjects although self-efficacy was related to both ability (mathematics aptitude test score) and prior achievement (high school achievement). In engineering, occupational and academic milestones self-efficacy were both significantly correlated with performance, with academic milestones self-efficacy being recognised as the strongest predictor of performance (Hackett et al., 1992). Notably, this study found that previous achievement did not predict performance directly.

While the studies mentioned above were able to identify a significant relationship between self-efficacy and performance, a lot of self-efficacy research has yielded ambiguous results, with some researchers discovering disparities between self-efficacy and achievement. Such disparities are often gender related. For example, Zander et al. (2020) found that in secondary education girls had much lower self-efficacy even when their grades in mathematics did not differ from that of boys. This was found to be true in tertiary settings as well, with Marshman et al. (2018) reporting that women students in introductory physics are less self-efficacious than male students, even when their performance is exceeding. Self-efficacy has also been found to be of low predictive value regarding the performance of first-generation students. Ramos-Sánchez and Nichols (2007) found that self-efficacy did not significantly influence the performance of first-generation university students and that first-generation students performed worse than non-first-generation regardless of their beliefs about personal capabilities across a variety of disciplines. Furthermore, self-efficacy can be a non-significant predictor of performance in the early stages of STEM university education. For example, Ainscough et al. (2016) found that performance in the final exam among students in a first-year biology course could be predicted by such variables as progressive grade, degree, and previous instruction in chemistry and biology, but not by self-efficacy. Although the relationship between self-efficacy and achievement is complicated and highly dependent on the specificity of self-efficacy measurement, study domain, and the background characteristics of the study participants, students' confidence beliefs clearly play an important role in predicting achievement and self-efficacy interventions could therefore be of pivotal importance in helping reduce underperformance among students from disadvantaged groups.

2.4 DEMOGRAPHIC SELF-EFFICACY MODERATORS

As showcased in Sections 2.2 and 2.3, self-efficacy research has produced a variety of contradictory findings, even when conducted in the same geographical context and domain. According to Mischel (1977), "when predictions are needed about individual differences in response to the same conditions, or when situational variables are weak, information about person variables becomes essential" (p. 251). Since self-efficacy is always context-specific, self-efficacy is "an ideal vehicle with which to explore the difference in perceptions of competence as a function of factors such as age, race, and ethnicity" (Pajares, 1996, p. 567).

The following subsections offer an overview of the key demographic factors that have been extensively examined as modifiers of self-efficacy beliefs. This study places primary emphasis on gender as the central lens of analysis, while also considering other significant factors including age, race/ethnicity, and socio-economic background.

2.4.1 Gender

The research on the role of gender on self-efficacy beliefs has been contradictory. According to Bussey & Bandura (1999), gender beliefs have a persistent influence throughout all stages and over all aspects of people's lives, as they have an impact on "the talents they cultivate, the conceptions they hold of themselves and others, the sociostructural opportunities and constraints they encounter, and the social life and occupational paths they pursue" (p. 676). In science, for example, the results of societal gender-typing are observed in the self-efficacy beliefs of children and adolescents: although boys and girls like science the same, parents perceive boys as more competent in science, think science is more important for boys, and expect more of boys (Andre et al., 1999). Girls have also been found to be more likely to report effort as the main cause of academic success and lack of ability and support as the primary reason for failure (1984). Recent research indicates that a significant number of aspiring math teachers still maintain gendered beliefs concerning the mathematical abilities of children (Dersch et al., 2022). As a consequence, girls hold consistently lower self-efficacy beliefs in mathematics (Zander et al., 2020), and science (Anderman & Young, 1994; OECD, 2015), regardless of their actual achievement level.

Gender beliefs formed during the primary and secondary stages of education play a vital role in the selection of a study domain and persistence in the chosen study programme. Bandura (1997) theorised that a clear distinction in self-efficacy beliefs regarding academic and career choices can be identified among different genders. Various studies throughout the years have found that being female is a negative predictor for choice of STEM university programmes (Betz & Hackett, 1981; Moakler Jr & Kim, 2014; Vooren et al., 2022). Accordingly, women tend to display lower self-efficacy beliefs for scientific occupations and occupations requiring quantitative skills and activities (Bandura, 1997); which implies that women in STEM disciplines are likely to be less self-efficacious than men. However, several studies found no difference in mean self-efficacy levels among STEM students of different genders. For instance, Lent et al. (1984) found that female and male students in technical and scientific majors held comparable self-efficacy beliefs, although the sample size of this study was small (n = 42). In engineering, Concannon and Barrow (2009) and Mamaril et al. (2016) found no statistically significant difference in self-efficacy scores between genders, although Concannon and Barrow did observe that women had lower coping-self-efficacy scores, and

Mamaril et al. found that women displayed slightly lower self-efficacy scores for the tinkering self-efficacy subscale.

Other studies, however, found significant gaps in perceived confidence among students of different genders across a range of STEM disciplines. In higher education, self-efficacy beliefs have been found to be only partially influenced by actual skill. This is particularly apparent when investigating the self-efficacy beliefs of female students in STEM fields. Women have been found to possess low self-efficacy beliefs, irrespective of their performance, in professions requiring quantitative skills (Betz & Hackett, 1981), and in mathematics at the secondary (Zander et al., 2020) and tertiary level (Betz & Hackett, 1983) of education. In undergraduate STEM contexts, women consistently reported lower self-efficacy in introductory engineering (Felder et al., 1995), physics (Marshman et al., 2018), chemistry (Dalgety & Coll, 2006), and biology (Ainscough et al., 2016) courses. The biggest differences between achievement and self-efficacy have often been identified among high-achieving women (Ainscough et al., 2016; Marshman et al., 2018).

In two comparative studies, Zeldin and associates (Zeldin et al., 2008; Zeldin & Pajares, 2000) identified significant differences between the way women and men interpret their experiences in STEM. Not only were men found to encounter fewer obstacles in their academic careers, but they also demonstrated a resilient sense of self-efficacy even in the face of adversity and did not question their scientific or social identity in the same way women did. Interesting discrepancies emerged in the way participants in both studies reflected upon their successes. While women participants repeatedly described the cognitive challenges they encountered in STEM education and emphasised hard work and stubbornness to persevere despite adversity as the main reasons for their success, men related their successes to innate ability (Zeldin et al., 2008; Zeldin & Pajares, 2000).

Since mastery experiences are considered one of the most reliable sources of self-efficacy information (Bandura, 1977a, 1986), one might assume that performance feedback could eliminate gender discrepancies by providing objective evidence for capability to successfully accomplish tasks. However, Marshman et al. (2018) found that during two semesters of instruction in introductory physics, female students consistently reported significantly lower self-efficacy at every performance level and in different learning environments. Interestingly, with more exposure to the course materials, the gap between the self-efficacy beliefs of female and male students grew, with the highest-performing students displaying the biggest discrepancies. Similar observations have been made in the context of introductory chemistry (Moreno et al., 2021). Although Moreno et al. (2021) found that in introductory and general chemistry courses self-efficacy increased progressively with exposure to course content across all students irrespective of gender or ethnicity, students with a double minority status (in this case, black female students) displayed the lowest growth (although the interaction effect between gender and ethnicity was not statistically significant). Attitudes about capabilities are influenced by students' university experiences, such as relationships with peers, pedagogical methods (further discussed in section 2.5), and institutional culture, and women may experience higher anxiety and lower self-efficacy in environments with a shortage of female role models and mentors (Felder et al., 1995), which could explain why women's STEM self-efficacy remains low despite having had successful mastery experiences.

The previously mentioned studies indicate that mastery experiences alone are not powerful enough to eliminate gendered self-efficacy differences in STEM university programmes. According to Schunk and Lilly (1984), this is because mastery experience can only improve academic self-efficacy in women when combined with explicit feedback. When investigating the self-efficacy beliefs of women in STEM majors and STEM-related careers, Zeldin and Pajares (2000) found that women relied primarily on vicarious experience and verbal persuasion in both personal and professional circles for self-efficacy information. Therefore, initiatives aiming to improve equity in STEM disciplines cannot rely on self-efficacy interventions centred around creating achievement opportunities alone.

2.4.2 Age

Significant links have been identified between self-efficacy beliefs and the age of the students. Students in secondary and higher education display higher self-efficacy scores than primary students (Multon et al., 1991). Multon and co-workers (1991) offer an interpretation that older students possess higher levels of self-efficacy based on vaster domain experience and greater knowledge of themselves, which allows for a more accurate self-appraisal. This finding was replicated in studies comparing the self-efficacy beliefs of university students of different ages. For example, Erb and Drysdale (2017) noted significant differences in self-efficacy beliefs between traditional age and mature undergraduate students across a variety of disciplines. Mature students (21 and over at the point of entry to their undergraduate programme) reported an overall greater sense of self-efficacy and indicated greater values of confidence in judgemental ability and activity persistence, with no significant differences identified between young mature (21-24 years of age) and mature (25 and above) students.

However, other researchers have reported less optimistic findings on mature students' self-efficacy. Lynch and Bishop-Clark (1994) found that many mature students were anxious about their performance, felt like their preparation for the course matter of their programme was lacking, and had insecurities regarding their academic potential. The lack of confidence among mature students is often the result of a variety of personal, professional, and institutional obstacles mature students face (Ritt, 2008), with mature female students struggling the most (Stone, 2008). Similar trends can be observed in STEM contexts as well. In undergraduate mathematics, Jameson and Fusco (2014) found that learners who had been classified as mature based on either their age (25 and above) or characteristics (gap between secondary and tertiary education/ (partial) part-time attendance/ full-time employment/ no financial support from legal guardians/ dependents other than a spouse/ single parent/ no high-school diploma) highlighted significantly lower levels of overall mathematics self-efficacy in comparison to traditional students. Although mature students' self-efficacy in more practical areas of mathematics (e.g., fractions and decimals) was comparable with that of traditional students, mature students expressed lower self-efficacy beliefs toward more theoretical aspects of mathematics, such as geometry and trigonometry. Aside from student age, the time since their last experience in math instruction also had a considerable influence on students' self-efficacy levels. Jameson and Fusco (2014) explained how a gap in formal mathematics education is especially detrimental to the self-efficacy beliefs of students in mathematics since they perceive their younger peers as more mathematically and technologically competent due to their recent graduation from school.

2.4.3 Race/Ethnicity

An achievement and opportunity gap concerning minority ethnic groups at university level is widely acknowledged. In the US, minority ethnic students have been reported to be less likely to complete STEM university programmes (Carpi et al., 2017) and to earn lower grades than their white and Asian peers (Whitcomb & Singh, 2021).

Research in European universities has yielded similar results. A Dutch study (Vooren et al., 2022) revealed that students with a migration background (students with at least one non-Dutch parent) are disadvantaged at both research universities and universities of applied sciences. The study found that students with a migration background were less likely to enrol in STEM university programmes at research universities and more likely to drop out during their first year than other students. In addition, students with a migration background were less likely to graduate from their STEM programmes on time in both types of universities.

Black students in STEM have been observed to make strategic academic decisions, choose academic paths in which they perceive themselves as more capable, and focus on gaining a degree, rather than selecting study courses based on interest and focusing on deepening their knowledge in the academic domain (Greaves et al., 2022). Hood et al. (2020) found that in an undergraduate STEM context, the self-efficacy beliefs of non-white students declined over the duration of an academic term, and non-white students performed worse and received lower final grades. Confidence beliefs of ethnic minority students are especially affected when racial discrimination intersects with gender inequalities (Idahosa & Mkhize, 2021).

A meta-analysis by Sheu et al. (2018) revealed a negative correlation between vicarious learning and the self-efficacy of ethnic minority students in self-efficacy research. According to Sheu et al. (2018), this is likely because “observation of similar others receiving less favorable treatment in STEM environments may have a dampening effect on the self-efficacy of persons who are underrepresented in these environments” (p. 131). This idea is supported by Greaves et al. (2022), who reported that black students’ confidence in STEM fields was affected by the recognisable ethnic inequality in their universities and professional fields. Greaves and co-workers (2022) also identified the lack of ability to relate to their white peers and instructors and having missed out on opportunities available to white students, as detrimental to the self-efficacy beliefs of black STEM students.

Since ethnic minority students are more likely to be first-generation students (Bui, 2002; Hood et al., 2020), they are exposed to an additional set of challenges, more closely described in subsection 2.4.4. When non-white students are also first-generation students, the decrease in self-efficacy over the course of an academic term in a STEM university programme is especially large (Hood et al., 2020). Similarly, MacPhee et al. (2013) observed that before joining a mentoring programme for academically promising STEM students, STEM students who were both ethnic minorities and came from a low SES background showcased lower academic self-efficacy, expressed less confidence in their test-taking abilities, and performed worse than single-minority students.

Some research investigating the links between race/ethnicity and self-efficacy has been conducted regarding individual STEM disciplines. For example, a self-efficacy gap has been identified in mathematics self-efficacy between black and white students (see Pajares, 1996). Ethnicity-dependent differences in self-efficacy subscales have been identified among students enroled in engineering university programmes as well. Hackett et al. (1992) observed differences in self-efficacy between Euro-American and Mexican-American students in engineering. In a more recent study by Concannon and Barrow (2009), some distinctive differences in the subscales of self-efficacy emerged between black and white students: black students had lower engineering career outcome expectations than white students and indicated lower scores in regard to perceived professional potential, feelings of belongingness, equal opportunities, and potential success in engineering careers, although no statistically significant differences in mean self-efficacy scores were identified. Villafañe et al. (2016) were able to identify differences in chemistry self-efficacy based on ethnicity both at the beginning of the semester and throughout the semester in a preparatory chemistry course. Similarly, when examining the effect of gender and ethnicity on self-efficacy in introductory and general chemistry, Moreno et al. (2021) observed that although self-efficacy increased over the course of a semester for students of all ethnicities, minority ethnic students were still less self-efficacious in specific areas of chemistry at the end of the semester when compared to the ethnic majority students. In introductory physics, some statistically significant differences among ethnic groups have been reported. Kalender et al. (2017) identified white and Asian students as having higher levels of self-efficacy in calculus-based physics courses than minority ethnic students at the beginning of the course, although no differences in self-efficacy were identified in algebra-based physics courses.

While previous findings reflect that a self-efficacy gap in STEM exists for underrepresented race and minority ethnic students in some STEM contexts, research also shows that initiatives targeting low self-efficacy in STEM tend to especially benefit underrepresented students, with previous studies finding that pedagogies addressing students' motivational characteristics (Ballen, Wieman, et al., 2017; Kalender et al., 2017) and mentoring (MacPhee et al., 2013) can successfully eliminate race/ethnic differences in undergraduate STEM courses. For instance, Ballen and colleagues (Ballen, Wieman, et al., 2017) found that introducing active learning pedagogies (with a focus on low-stake pre-class assignments and quizzes, collaborative work on structured problems in assigned groups, graded personal response systems, and cumulative assessment) helped increase self-efficacy and improve course performance among underrepresented minority students.

2.4.4 Socio-Economic Background

Socioeconomic background also has a significant effect on self-efficacy throughout all stages of education. The self-efficacy and academic achievement of secondary school pupils are influenced by the expectations their family members have for them and the beliefs they hold about being able to influence their children's learning (Bandura et al., 1996; Zimmerman et al., 1992). In a study with 12–14-year-olds, Bandura (1996) discovered that parents with higher socioeconomic statuses (identified through the occupation of the father of the child participating in the study) are more likely to believe in their ability to enhance their children's learning and have higher aspirations for their children. Children respond to the expectations of their parents by exhibiting a higher sense of self-efficacy in regard to being able to manage their learning and succeed at school and by engaging in prosocial behaviour, with children from families of high socioeconomic statuses displaying higher capability to resist peer pressure and lesser involvement in activities that can prove distracting from academic pursuits (Bandura et al., 1996).

At university level, socioeconomically disadvantaged students are less likely to major in STEM than students from backgrounds of higher socioeconomic status (Shaw & Barbuti, 2010) and have a lower sense of self-efficacy, especially in combination with belonging to other marginalised groups on the basis of gender or ethnicity (Hood et al., 2020; MacPhee et al., 2013). While the socioeconomic background of children is usually identified by their parents' occupations, the socioeconomic background of university students is often correlated with whether or not their parents/legal guardians had a university education, since first-generation university students are most likely to come from a lower socioeconomic background (Bui, 2002).

First-generation students are not only more likely to come from low-income families, but they are also more likely to belong to racial and ethnic minority groups underrepresented in higher education (Bettencourt et al., 2020). They are therefore often exposed to cumulative disadvantage and their lower performance and higher attrition rates are better explained by "inequitable access to economic and educational opportunities" (Bettencourt et al., 2020, p. 768) that influence their academic trajectories rather than generational status alone.

When it comes to first-year students, first-generation students are exposed to a unique set of obstacles: they tend to be more afraid of failure, have concerns about financial aid, and express feeling that they must put in more time than continuing-generation students into studying (Bui, 2002). Prior research has identified a self-efficacy gap between first-generation and continuing-generation students (Bui, 2002; Ramos-Sánchez & Nichols, 2007). Unsurprisingly, first-generation students have also been found to perform worse than their continuing-generation peers (Bettencourt et al., 2020; Hood et al., 2020; Ramos-Sánchez & Nichols, 2007; Sirin, 2005). Ramos-Sánchez and Nichols (2007) found that generational status influences performance in a way that cannot be mediated by self-efficacy, with first-generation students performing worse than their peers regardless of how self-efficacious they are. However, taking into account that first-generation students are more prone to stress and anxiety (Hood et al., 2020) and have a greater risk of dropping out of their university programme (Bettencourt et al., 2020), self-efficacy interventions for first-generation students could prove effective in supporting persistence and retention.

As illustrated throughout section 2.4, student background characteristics can drastically alter their university experiences. As such, it is not surprising that the self-efficacy beliefs of students from marginalised groups are often vastly different from their peers. The cumulative disadvantages students from multiple minority groups are exposed to are often the reason for some of the lowest self-efficacy scores overall. However, multiple studies investigating pedagogical interventions have reported that marginalised students' self-efficacy beliefs can be influenced via considerate pedagogical practice. In fact, students from marginalised groups often profit from pedagogical self-efficacy interventions the most.

1.4 RELATIONSHIP BETWEEN PEDAGOGY AND ACADEMIC SELF-EFFICACY

Pedagogies that embrace active learning (Fencl & Scheel, 2004), provide students with ample feedback and support (MacPhee et al., 2013), and employ considerate assessment practices (Malespina & Singh, 2022) are known to positively contribute to students' self-efficacy in STEM. According to Bandura (1977; 1986), providing one with many achievement opportunities helps build a robust sense of self-efficacy and make one less likely to be affected by occasional failures. Therefore, even achievement opportunities involving challenging tasks that require an extensive amount of effort can reinforce students' self-efficacy, since self-efficacy is concerned with capability and not skill and being able to overcome challenges through hard work and persistence proves that success in dealing with difficult tasks is achievable.

While some researchers (Bailey et al., 2017; Carpi et al., 2017) have suggested that creating plentiful achievement opportunities is instrumental to students' confidence in their capability to successfully perform in STEM, many recommend including more frequent and less ambitious projects in STEM course curricula in order to avoid failures that might be crippling to students' self-efficacy, especially in undergraduate STEM contexts. For example, in undergraduate chemistry, Dalgety and Coll (2006) found that since chemistry self-efficacy is significantly affected by performance accomplishments, creating achievement opportunities is the most straightforward way to provide chemistry students with a chance to improve their self-efficacy beliefs. While not inferring that achievement opportunities should involve underchallenging coursework, Dalgety and Coll suggested that introducing more smaller-scale test work, such as solving worksheets or quizzes, may help students become progressively more confident in their chemistry classes. In undergraduate physics, Malespina & Singh (2022) made a similar point, bringing attention to how providing students with regular low-anxiety achievement opportunities in introductory physics did not only contribute to the development of student study and exam skills and provided students with vital feedback, but also helped decrease anxiety towards high-stake examinations.

Mentoring has also been identified as indispensable in helping bolster the self-efficacy of students underrepresented in STEM fields. MacPhee et al. (2013) examined how self-efficacy and performance indices of minority STEM students changed over the course of a mentoring programme for selected academically promising minority STEM students and found that women benefitted most from the programme. Although women in this study showed significantly lower levels of self-efficacy at the beginning of the programme, after completing the mentoring programme their academic self-efficacy increased by 0.61 standard deviations (SDs) closing the self-efficacy gap between men and women. Furthermore, Carpi et al. (2017) found that mentored research programmes helped underrepresented undergraduate STEM students realise their academic potential and increased their confidence and ambition when planning further studies. Carpi et al. (2017) study demonstrated that mentored research was a very effective way to influence intentionality to pursue postgraduate STEM programmes, as it helped the students develop skills necessary for postgraduate study and prove themselves as potential researchers, thus making students consider academic pathways they could have deemed unattainable in other scenarios.

Other studies found that pedagogies incorporating multiple sources of self-efficacy information have the best odds to improve students' self-efficacy. For instance, in introductory astronomy, Bailey et al. (2017) found that teaching practice was directly related to changes in self-efficacy, with self-efficacy being highly influenced by the opportunities for mastery experiences, types of verbal persuasion, and vicarious learning opportunities. Students reported the highest self-efficacy improvements in classes that provided ample opportunities for students to prove their knowledge and skills, employed an undergraduate teaching assistant, and in which coursework was accompanied by elaborate performance-related feedback. Students in classes in which only exams, quizzes, and homework were administered, which did not use teaching assistants or only used them for administrative tasks, and in which feedback was scarce, did not report improvement in self-efficacy. Other pedagogical practices negatively affecting student-self efficacy in astronomy included placing stress on individual learning rather than providing students with in-class learning opportunities, counting on students to seek out feedback themselves (e.g., during office hours), and blaming student failure on lack of effort (Bailey et al., 2017). Other studies have highlighted the importance of learning-focused pedagogies and found that teachers who engage in pedagogical practices highlighting student ability (displaying the work of highest achievers/ giving high-achieving students special treatment/ saying other students should look up to highest-achieving students) can negatively affect student motivation in science learning (Anderman & Young, 1994).

Active learning strategies and their effect on undergraduate STEM self-efficacy have particularly received much attention in self-efficacy research. Some studies reported significant gains in self-efficacy among all students. For instance, Dunlap (2005) found that using problem-based learning in a software engineering course with computer science students in their final semester helped them drastically improve their self-efficacy: their mean self-efficacy score improved from 22.07/40 at the beginning of the semester to 37.90 at the end of the semester. Fencl, Scheel, and associates (Fencl & Scheel, 2005; Fencl & Scheel, 2004; Scheel et al., 2002) have continuously reported strong correlations between active learning pedagogies and student self-efficacy in introductory chemistry and physics courses. Other studies praise active learning for benefitting underrepresented students in particular. For instance, Ballen and colleagues (2017) found that transitioning from traditional lecturing to active learning in a large lecture classroom helped increase the self-efficacy of all students and close the gap in learning gains between non-underrepresented minority and underrepresented minority students.

However, active learning in the STEM classroom has also received some criticism. For example, researchers warn about using active learning without focusing on equity and inclusion in mathematics (Reinholz et al., 2022) and physics classrooms (Kalender et al., 2020; Marshman et al., 2018). When investigating active learning pedagogies in undergraduate mathematics, Reinholz and associates (2022) found that in 15 out of 20 cases, inquiry-oriented instruction led to gendered inequalities regarding participation and, in turn, performance. Since for women in this study, talk-based participation predicted their performance, unequal participation patterns in inquiry-oriented learning environments were found to undermine female students' success in undergraduate mathematics. In physics classrooms, researchers are concerned with gendered patterns of participation as well.

Kalender et al. (2020) mentioned how, in order for active learning courses to promote equality, classes must be carefully facilitated to embrace the contribution of every student and to promote a safe environment for self-expression. Since women tend to be in charge of less intellectually demanding, more clerical tasks (Felder et al., 1998) and men are prone to dominating group-work scenarios (Dalgety & Coll, 2006; Kalender et al., 2020), all collaborative initiatives have to be carefully supervised and moderated to help accommodate non-male students and create a more equitable learning environment. For example, assigning individual roles in collaborative projects helps avoid group activities being dominated by one student (Theobald et al., 2017). When facilitated effectively, however, collaborative learning is a great tool for improving self-efficacy, especially in undergraduate programmes in physical sciences (Fencl & Scheel, 2004; Scheel et al., 2002).

Another point of criticism active learning is often exposed to is its contribution to student stress. Although STEM university programmes are generally considered stressful, women have been consistently found to exhibit higher anxiety levels than men (Ballen, Salehi, et al., 2017; Malespina & Singh, 2022; Mallow, 1994). Other studies have identified racial/ethnic minority students and first-generation students (Hood et al., 2020), as well as students with high generalised (England et al., 2017) and social anxiety (Cohen et al., 2019), as risk groups, who, due to experienced stress, may perform worse and be more prone to attrition in active learning environments. Therefore, in order for active learning to contribute to creating a more equitable learning environment, low-anxiety, active learning strategies should be prioritised (Lübeck et al., 2022). Dalgety and Coll (2006) found that collaborative work is well enjoyed among first years because of its informality and suggested facilitating collaborative work in relaxed learning environments to encourage academic exchange. In addition, allowing students to choose their partners for collaborative tasks freely helps decrease anxiety (Cooper et al., 2018) and benefits marginalised and minority groups in particular (Cooper & Brownell, 2016; Eddy et al., 2015).

A lot of research has focused on comparing practical and theory-based modes of STEM learning. Since the relationship between self-efficacy and performance is reciprocal, pedagogies that help best improve learning outcomes should best influence student self-efficacy. However, findings on theory-based learning and practice-based learning on student performance have been divisive. Some research shows that student-centred instruction, which is based on practical learning, produces higher science performance outcomes (Freeman et al., 2014; Granger et al., 2012). Other studies have shown that active-learning approaches have a negative effect on long-term knowledge retention compared with lecture-based learning (Taglieri et al., 2017). Studies comparing the direct effects of practice-based learning vs traditional lectures on student self-efficacy have not been conclusive either. While Schauber and colleagues (2015) found no differences in student self-efficacy or achievement between the traditional curriculum and problem-based-learning curriculum, a study by Ballen and co-workers (2017) found that a switch from traditional lecturing to active learning resulted in a significant increase in self-efficacy and performance gains for underrepresented minority students.

2.6 SELF-EFFICACY MEASUREMENT

Perhaps one of the most persistent issues in self-efficacy research has been the lack of unanimity in the interpretation of self-efficacy as a concept. Pajares (1996) has expressed that the reason for some confusion over what self-efficacy entails has to do with self-efficacy's overlap with other expectancy belief concepts (1996). Therefore, self-efficacy has often been operationalised inaccurately (Usher & Klassen, 2010). Several self-referent constructs in psychosocial research relate to or are seemingly similar to self-efficacy, such as self-concept, effectance motivation, and outcome-expectancy theories (Bandura, 1986). For this study in particular, it is important to address the contentious relationship between self-efficacy and outcome expectancies as well as to understand the difference between self-efficacy and self-concept, as the two concepts are difficult to differentiate when self-efficacy is measured at a domain-specific level (Skaalvik & Skaalvik, 2007), which is the case with this study.

2.6.1 Self-Efficacy vs Outcome Expectancies

The motivational theories of self-efficacy and expected outcomes are both part of Bandura's (1986) social cognitive theory. They have both been found to have a significant influence on peoples' academic and professional lives since they can "promote interest in particular educational and occupational tasks and domains and, along with interests, to motivate goals and actions in pursuit of career-relevant paths" (Sheu et al, 2018, p. 119). Although self-efficacy and expected outcomes influence the same aspects of academic and professional functioning, the two constructs are distinctive and should not be treated as "the same phenomenon measured at different levels of generality" (Bandura, 1997, p. 20).

Self-efficacy beliefs reflect personal judgements about capabilities to successfully perform given types of tasks regarding particular academic or career contexts (Bandura, 1986, 1997). Outcome expectancies, on the other hand, are concerned with beliefs about the results and consequences behaviour will produce (Lent et al., 1994; Sheu et al., 2018). These consequences fall under three main categories: physical effects, social effects, and self-evaluative reactions (Bandura, 1997). Positive outcome expectations work as incentives, while negative outcome expectations act as disincentives (Bandura, 1986, 1997). Since the motivation to act is influenced by the appeal of future outcomes and the probability of achieving those outcomes, in educational settings, motivation to act is affected by the belief that effort will result in increased performance (Geiger & Cooper, 1995).

According to Lent et al. (2013), the difference between self-efficacy and outcome expectancies is best transmitted through the questions “Can I do it?” and “What will happen if I try?” (p. 562) In other words, while self-efficacy gauges judgments of personal competence to execute a task, outcome expectancies are concerned with the consequences executing a task will evoke (Bandura, 1997). Confidence regarding capabilities can influence the expected outcomes of one’s behaviour (Bandura, 1997). Those confident in their own abilities expect success, while those lacking confidence anticipate failure. However, self-efficacy can only influence outcome expectations “in situations where the quality of performance guarantees particular outcomes” (Lent et al., 1994, p. 84). In situations where outcomes are less predictable, self-efficacy and outcome expectations have “little or no relationship to each other” (Bandura, 1997, p. 20).

When comparing the influence of self-efficacy and outcome expectancies, Bandura (1986, 1997) claims that self-efficacy is a better and more consistent predictor of behaviour. Bandura also argues that in performance situations, efficacy beliefs “account for most of the variance in expected outcomes” (1997, p. 24). Highly efficacious people do not cease their efforts when not gaining expected outcomes and instead increase their efforts or try and identify the reasons outside their control (e.g. inequitable social practices) for why they are not getting expected results (Bandura, 1997). People with high outcome expectancy and low self-efficacy beliefs, however, are more prone to giving up upon failure to achieve expected results (Bandura, 1997). Nevertheless, the influence of self-efficacy and outcome expectations on behaviour is difficult to generalise, as it affects behaviour differently in different contexts and regarding different tasks and the influence of self-efficacy and outcome expectancies on behaviour is often cumulative. For instance, people with high self-efficacy and high outcome expectancies are most likely to engage in productive behaviour, while those with low self-efficacy and outcome expectations are more prone to apathy and resignation (Bandura, 1997). High self-efficacy and low outcome expectations (e.g. due to social inequality) may result in protest or grievance, while low self-efficacy and high outcome expectations cause self-devaluation (Bandura, 1997).

One of the criticisms Bandura has received regarding his social cognitive theory has been the depiction of the relationship between self-efficacy and outcome expectations as non-reciprocal. While Bandura has only described the effect of self-efficacy on outcome expectancies, many studies have proved that outcome expectations can influence self-efficacy as well (see Pajares, 1996 and Williams, 2010, for reviews). This is not surprising, as “the direction of causality among motivational variables is seldom unidirectional” (Bong, 1996, p. 161).

According to Pajares (1996), “subsuming beliefs of personal efficacy under other motivation constructs can be problematic in that it can obfuscate important differences between the self beliefs and minimize the unique contribution that self-efficacy perceptions make to an understanding of motivation and behavior” (p. 557). In order for self-efficacy to be measured independently from outcome expectancies, some researchers propose introducing the phrase “if I wanted to” in the items of the self-efficacy questionnaire or explicitly informing respondents that perceived capability is independent of expected outcomes (Williams, 2010) (p. 422). However, this study believes that using “can do” items and avoiding the usage of "will do" items in the self-efficacy questionnaire, as advised by Bandura (1997) (e.g. "I can achieve a good grade in this class" vs "I will achieve a good grade in this class") is enough to encourage students to evaluate their capabilities rather than reflect on the probability of specific outcomes.

2.6.2 Self-Efficacy vs Self-Concept

While both self-efficacy and self-concept have been highly important in educational research, the difference between the two concepts is sometimes difficult to grasp. According to Bong and Skaalvik (2003), the distinction between the two lies in that self-concept reflects more general feelings about "individuals' knowledge and perceptions about themselves in achievement situations", while self-efficacy is concerned with "individuals' convictions that they can successfully perform given academic tasks at designated levels" (p. 6). Self-efficacy reflects perceived competence to perform at a designated level in situations that are highly context-specific, while self-concept is less context-dependent and gauges self-knowledge and feelings of self-esteem in relation to a specific domain (Bong & Skaalvik, 2003; Pajares, 1996). To illustrate, a student's sense of self-concept might have to do with their general estimation of their ability (I am good at science), comparison with other students (I am better at science than my peers), comparison with other subjects (I am better in science than I am in literature), or interest/sentiment (I am interested in science/ I like science). Self-efficacy beliefs are much more contextual and deal with specific confidence beliefs towards specific tasks (I am confident that I can learn the material in my science courses this semester/ I am confident that I can perform well on the next science assignment). Researchers have suggested that, in simple terms, self-concept is concerned with *ability*, while self-efficacy reflects *capability*, and that self-concept gauges *perceived competence* while self-efficacy measures *perceived confidence* (Bandura, 1986; Bong & Skaalvik, 2003).

Self-efficacy and self-concept differ in their function and do not always correlate. As Pajares (1996) noted, students "may feel highly efficacious in mathematics but without the corresponding positive feelings of self-worth" (p. 561). Both concepts have been proved to affect engagement, motivation, persistence, performance, and career planning (Bong & Skaalvik, 2003). However, depending on the aspect of academic functioning being measured, self-efficacy and self-concept may be differently influential; for instance, Pajares and Miller (1994) found self-efficacy to have a stronger effect on mathematical problem-solving ability than self-concept.

Since self-concept is never task-specific, the difference between domain-specific self-concept and task-specific self-efficacy is easy to distinguish. The two concepts become much less distinctive when they are both measured at a domain-specific level (Skaalvik & Skaalvik, 2007). Bong and her associates have been instrumental in outlining the differences between the two concepts at a domain-specific level (Bong, 2006; Bong & Skaalvik, 2003).

According to Bong (2006) and Bong and Skaalvik (2003), although both self-concept and self-efficacy primarily rely on self-reports as a data collection method, significant differences in measured indices and question formation need to be considered. When measuring self-concept, questions about competence may be accompanied by questions about the student's sentiment towards the domain and measure interest, satisfaction, enjoyment, and overall usefulness of the domain. Additionally, the measurement of academic self-concept draws upon comparison (both with other students and other domains). Since self-concept is not context-dependent, when measuring self-concept, students are asked to express general feelings of competence regarding a specific domain. Therefore, self-concept is informed by past experiences and provides a rather stable projection of one's competence in a specific field.

Self-efficacy, on the other hand, measures self-reported capability without evaluating emotional responses or involving comparison to others. Rather than reflecting general ability, self-efficacy measures perceived capability in relation to specific performance goals and the items on self-efficacy measurement instruments provide specific benchmarks against which perceived capability should be evaluated. The goal-oriented nature of self-efficacy assessment requires the students to make future-oriented evaluations. Self-efficacy beliefs are more susceptible to change than self-concept and can vary greatly within a domain when assessed in relation to different tasks. Therefore, the specificity at which self-efficacy is measured needs to be carefully considered.

2.6.3 Specificity of Self-Efficacy Measurement

Another issue concerning self-efficacy measurement in academic research concerns disagreements over the level of specificity required to obtain valid self-efficacy information. Self-efficacy is always context-specific and can be skill-specific, task-specific, or domain-specific (Bandura, 1997; Bong, 2006). In order to ensure that self-efficacy information is most accurate and has high predictive value, instruments measuring self-efficacy should be criterial task-specific, domain-specific, and applied as closely in time as possible to the criterial task (Lent & Hackett, 1987; Mischel, 1977; Pajares & Miller, 1995).

Many researchers warn against the global measurement of self-efficacy. Some suggest that instruments measuring self-efficacy at a more general level may provide unreliable self-efficacy information since they fail to incorporate the contextual factors necessary for accurate self-efficacy judgments sufficiently (Bong & Skaalvik, 2003). Others suggest that more specific measurements will provide findings of higher predictive value. For instance, Joo et al. (2000) and Multon et al. (1991) found that stronger relations with performance indices could be indicated when the self-efficacy measures were task-specific.

However, this does not mean that instruments measuring self-efficacy at a more general level should be discounted. According to Bandura, it is possible to assess self-efficacy at varying levels of specificity depending on the researcher's intention (Bandura, 1997). Research in the field of self-efficacy has shown that significant insights and relationships between variables can still be established with self-efficacy measures that are not task-specific, as long as they remain domain-specific (Multon et al., 1991; Pajares & Miller, 1995). Especially in relation to establishing the relationship between self-efficacy and performance on a broader scope (e.g., course grades or overall GPAs), self-efficacy should be assessed at a correspondingly more general level, ensuring consistency with the criterial task (Pajares & Miller, 1995; Randhawa et al., 1993; Zimmerman et al., 1992).

2.7 THE CURRENT STUDY

The factors influencing self-efficacy outlined in the literature survey helped inform the data collection phase of this research. The participants of this study were asked to provide information regarding their gender, age, race or ethnicity, socio-economic background (generational status), and previous performance. It is hoped that considering the effects unique student characteristics have on their academic confidence will not only reflect the multifaceted nature of self-efficacy beliefs but also provide some valuable insights about which student groups may require the most support in the setting of higher education.

The literature review has also outlined some of the theoretical guidelines relevant to this study. The self-efficacy measure used in this study has been carefully selected to conform with the recommendations regarding the consistency with the theoretical principles of self-efficacy research and specificity of self-efficacy measurement. The self-efficacy instrument including items which measure perceived capability exclusively was selected and adapted to match the specific outcome measured in this study, namely class-specific self-efficacy. The correspondence between the self-efficacy measure and criterial task allowed study participants to make precise judgments of capability and facilitated the analysis of the relationship between classroom practice and student confidence.

Based on the literature review, it was apparent that certain knowledge gaps in self-efficacy research still exist. For instance, the knowledge about student self-efficacy and its relationship with pedagogical practice in the context of Irish higher education is limited. In addition, previous research regarding gender equality in education has often ignored the perspectives of gender minority students. Therefore, it is hoped that this study will make a unique contribution to the existing knowledge about student self-efficacy by addressing those knowledge gaps. Furthermore, while studies discussed in chapter 2 have investigated the effects of pedagogy on student confidence within a particular discipline, this study explored how student self-efficacy correlates with pedagogical practice in a more general context of STEM education and took the effect the educational environment (class type, class size, and instruction week) has on student self-beliefs into consideration. It is hoped that the level of detail provided in this study will help produce findings that are easily transferable and applicable in a wide variety of instructional settings.

3. RESEARCH DESIGN

3.1 RESEARCH METHODOLOGY

This study employs case study methodology and is centred around the paradigm of critical theory since it deals with issues of equity, inclusion, and representation in higher education. Although the critical theory approach to case study research is quite new, it has been theorised to offer “rich potential” (Cohen et al., 2018, p. 181). Case studies are known to help provide specific examples to more global issues and offer a detailed insight into the perspective of unique people in unique situations (Cohen et al., 2018). Moreover, the case study approach is well-suited to exploring causal relationships, aligning seamlessly with this study’s aim to assess the impact of specific pedagogical practices on student self-efficacy by comparing observed teaching methods with student self-reports.

In educational research, case study methodology is recogniaed for its capacity to deliver in-depth, contextually rich analyses, thanks in part to its focused scope. While case studies may sometimes face criticism for their limited generalisability, their findings remain highly applicable due to the detailed descriptions they offer (Kimmons & Caskurlu, 2020). In addition, the careful selection of methods and methodological triangulation can significantly enhance the generalisability of a case study’s findings.

3.1.1 Sampling

As is typical with case studies, non-probability sampling was used for self-efficacy surveys, class observations, and the focus group. Non-probability sampling is appropriate for research that does not aim to generalise the findings beyond the sample in question or intend to represent the undifferentiated population (Cohen et al., 2018). Since this study aimed to provide insight into the effects of teaching practice on the self-efficacy beliefs of undergraduate STEM students specifically, non-probability sampling was deemed appropriate.

The two methods of non-probability sampling used in this study were purposive and voluntary response sampling. An invitation to participate in the study was distributed to a number of STEM faculty members. The invitation was also extended to several instructors in first-year STEM modules identified through the university's timetabling platform. STEM classes selected for observation included first-semester classes only. Female and gender minority students who took the self-efficacy survey were invited to participate in the focus group interview at a later point. Students willing to participate in the focus group interview could register their interest by providing their contact details in an online registration form disconnected from the self-efficacy survey.

3.1.2 Methods

This study involved methodological triangulation and used both quantitative and qualitative means of data collection. According to Cohen and colleagues (2018), triangulation "is a powerful way of demonstrating concurrent validity" (p. 112). The multimethod approach allows for better generalisability and more objectivity in research findings, especially when the methods selected are very different from each other (Cohen et al., 2018; Erickson, 2020), which was the case with this study.

3.1.3 Instruments

Self-efficacy questionnaires, class observations, and a focus group interview were used to collect quantitative and qualitative data for this study.

Self-efficacy questionnaire

When conducting research rooted in critical theory, it is essential that the application of quantitative methods be carefully considered. It is widely acknowledged that quantitative approaches may have limitations in capturing the multifaceted nature of the research topic with the desired depth and complexity. However, quantitative methods can be considered appropriate in critical theory research if they align with the theoretical perspectives employed in the study and contribute to answering the research questions (Morrow & Brown, 1994). To ensure the suitability of the quantitative instrument utilised in this study, a meticulous selection process was undertaken. Specifically, the quantitative instrument was chosen to strictly adhere to established guidelines for self-efficacy research, as outlined by Bandura (2006). Adhering to these guidelines mitigated the risk of conflating self-efficacy with other self-referential constructs prevalent in psychosocial research. Moreover, it was important to collate the quantitative data collected through the chosen instrument with information concerning student backgrounds to facilitate a nuanced understanding of the interconnected relationship between student self-efficacy and their social identities. Therefore, the self-efficacy questionnaire was preceded by a short survey on students' backgrounds and prior academic performance. The information obtained from this survey served as a foundational basis for the subsequent critical analysis of the questionnaire results.

The administered questionnaire was digital, however, students that had issues accessing the online questionnaire or preferred to fill out a paper copy were provided with paper questionnaires (see Appendix 1). The self-efficacy questionnaire was preceded by a short (7-item) survey on students' backgrounds and prior academic performance. Taking previous research on confidence and competency beliefs in academic settings into consideration, questions regarding the age (Erb & Drysdale, 2017; Jameson & Fusco, 2014), gender (Han et al., 2021; Zeldin et al., 2008), race/ethnicity (Kalender et al., 2017; Moreno et al., 2021), socio-economic background (Bui, 2002; Ramos-Sánchez & Nichols, 2007), and prior academic performance (Bong, 2001; Villafañe et al., 2016) were included in the questionnaire. Questions regarding the socio-economic background and prior academic performance were formulated in accordance with previous research. Since first-generation status and low-income status were found to be concordant in previous research (MacPhee et al., 2013), the questionnaire prompted the participants to identify whether they were first-generation students. When selecting the best way to collect information about students' prior performance two major factors were considered: reliability of self-reported prior performance and the most appropriate performance indicator. When exploring the relationship between academic self-efficacy and prior academic performance, both performance in related school subjects and in standardised achievement tests can be predictive of self-efficacy in undergraduate courses (Hackett, 1985). Students were asked to provide their Leaving Certificate points, on the assumption that higher Leaving Certificate points would be indicative of students' achievement status. While previous meta-analyses of self-efficacy studies have expressed doubt in the validity of self-reported achievement scores, Honicke and Broadbent (2016) found that whether student achievement was self-reported or based on official marks had no significant influence on the relationship between performance and self-efficacy. Furthermore, although examination scores are not always the most appropriate measures of student performance, Marshman and associates (2018) found that important discrepancies between self-efficacy and performance were observable "regardless of whether performance was measured through research-validated instruments or through the performance indicators provided to students (i.e., grades)" (p. 12). Therefore, the questionnaires were designed to collect data on self-reported Leaving Certificate scores.

The self-efficacy questionnaire comprised 4 Likert-type scale questions to measure class-specific self-efficacy. Since simplified Likert-type scales have been identified as valid when investigating differences in confidence beliefs (Maurer & Andrews, 2000), a four-point Likert-type scale developed and validated by Han and associates (Han et al., 2021) was selected and adapted to represent the classes of the study participants (Table 1).

Han and colleagues' survey was originally designed to measure the self-efficacy of students in both humanity and quantitative classes and was therefore broad enough to use across a variety of STEM courses. All of the original items were maintained, however, the two items referring to different modes of assessment were adjusted to ensure a clear distinction between them. Each item was adapted to correspond to the class in which the self-efficacy questionnaire was administered.

Table 1. Self-Efficacy Survey Items

Original (Han et al., 2021)	Adapted
How confident are you that you can do the following tasks in your [quantitative/humanities] classes, which include subjects such as [subject names]?	How confident are you that you can do the following tasks in your [class name] class?
1. understand the most difficult concepts taught in my [quantitative/humanities] classes	1. understand the most difficult concepts taught in your [class name] class
2. master the skills taught in my [quantitative/humanities] classes	2. master the skills taught in your [class name] class
3. do well on the assignments in [quantitative/humanities] subjects	3. do well on the assignments (continuous assessment, as well as ungraded homework and in-class activities) in your [class name] class
4. do well on tests in [quantitative/humanities] subjects	4. do well on exams in your [class name] class

The scale was tested for internal consistency using Cronbach's alpha. Internal consistency helps identify whether the items on the scale are related to each other and thus can be assumed to measure the same construct. The coefficient alpha value was 0.887, which suggested that the items were strongly related to each other and that the adapted scale was internally consistent.

Class observations

15 non-participatory observations were conducted in undergraduate STEM courses. Three different types of classes (lecture, laboratory, and tutorial) were observed. Observations were selected as a method of data collection for two main reasons. Firstly, observation of real-life interactions is the most straightforward way to collect data for studies about human behaviour (Mischel, 1977). Secondly, observations were seen as a vital addition to other methods of data collection employed in this study. Class observations are a valuable supplement to interviews about matters concerning teaching and learning since they allow the researcher to make real-time first-hand observations and collect important information about behaviour that interview participants might find difficult to recall or deem not significant enough to mention. Class observations are immensely helpful when triangulating data collected from questionnaires as well. Structured surveys are sometimes prone to bias since the language they use can influence the data collected, and conducting observations can help the researcher obtain the full picture of the situation at hand (Cohen et al., 2018). When researching academic self-efficacy in particular, Pajares (1996) advises researchers to "assess both the sources and the effects of self-efficacy through direct observation" and to explore relationships between variables influencing self-efficacy "in real classroom contexts" (p. 566). Thus, the classes in which the self-efficacy questionnaire was administered were also observed.

This study utilised a structured approach to classroom observations, which is recognised for its systematic nature and capacity to gather numerical data, facilitating subsequent quantitative analysis (Cohen et al., 2018). In accordance with established guidelines for structured observations, the researcher assumed a non-participatory role during data collection. This non-participatory approach enhances the validity and reliability of the collected data, as it aligns with the consensus that low-interference observation allows for most objectivity (Cohen et al., 2018).

The Classroom Observation Protocol for Undergraduate STEM (COPUS) was followed during the observations, which "captures the actions of both instructors and students but does not attempt to judge the quality of those actions for enhancing learning" (Smith et al., 2013, p. 621). The COPUS employs instantaneous sampling in which observations about occurring behaviour are coded at set intervals of time (every 2 minutes). The coding sheet for one of the observed classes is included as an example in Appendix 2.

Focus group interviews

It is useful for quantitative research on academic self-efficacy to be complemented by qualitative research (Pajares, 1996). While surveys are a practical and quick method to generate data, they are deemed overused in self-efficacy research and may not always present the most accurate results, which is why researchers are often advised to consider interviews as a data collection method in self-efficacy research (Bartimote-Aufflick et al., 2016). In studies exploring human behaviour in particular, researchers are encouraged to treat study participants "as active colleagues who are the best experts on themselves and are eminently qualified to participate in the development of descriptions and predictions - not to mention decisions – about themselves" (Mischel, 1977, p. 249). Interviews as a data collection method help achieve exactly that by granting the participants in the study more agency than a survey is able to. According to Zeldin at al. (2008), relying solely on surveys can "fail to capture the development of an individual's academic self-perceptions", while interviews encourage participants "to elaborate on those experiences that have been most salient to them over time" (p. 760).

Group interviews can be especially useful in qualitative research since they allow the discussion to develop naturally and generate more responses (Cohen et al., 2018). Focus groups, in particular, are known to be exploratory in nature and allow for a freer and more natural expression of individual perspectives (Cohen et al., 2018; Vaughn et al., 1996). This study employs a case study methodology and case studies are notably concerned with the lived experiences of the participants (Cohen et al., 2018). Taking this into consideration, it was important to facilitate a focus group in order for the participants "to be allowed to speak for themselves rather than to be largely interpreted, evaluated or judged by the researcher" (Cohen et al., 2018, p. 182).

3.4 DATA ANALYSIS

Quantitative data (survey and observation results) were analysed using IBM SPSS Statistics. Descriptive and statistical analyses were employed to explore the relationships between student self-efficacy in this sample, the demographic self-efficacy moderators discussed in the literature review (gender, age, ethnicity/race, and generational status), study field, and previous performance. Chi-square tests were used to explore relationships with nominal moderators, while Kendall's Tau-B was employed to explore ordinal-ordinal correlations. Statistical analyses were performed with the self-efficacy variable grouped into categories of low, moderate, and high confidence, rather than the cumulative self-efficacy score, and the parametric interpretations (e.g. means) of the cumulative score were utilised for the purposes of descriptive statistics only. In addition to the factors relating to students' demographic and academic background, variables relating to the setting of the class in which the self-efficacy survey was administered (class type, class size, and instruction week) were tested for possible correlation with student self-efficacy.

Classification tree analysis, also called decision tree analysis, was employed to explore the effects of teaching practice on student confidence in a lecture setting. Specifically, CRT (Classification and Regression Tree) was selected as the growing method, for its acknowledged applicability to pedagogical research (Seftor et al., 2021). CRT analysis is straightforward to understand because it uses a tree-like structure, where each branch represents a different variable upon which the study participants are divided into homogeneous groups (nodes). The resulting tree diagram allows us to make predictions about the students based on the data. In the case of this study, it was used to investigate which teaching and learning practices can predict a larger number of confident students in a lecture environment.

The student self-efficacy variable was transformed into a new variable consisting of two categories only ('not confident' and 'confident') to help provide a more distinctive analysis of what pedagogical approaches lead to the student classification into the target group ('confident'). The analysis was cross-validated with 10 sample folds. It produced 7 nodes. Minimum numbers of cases were set to help prevent overfitting and improve the accuracy of the model (minimum number of cases in parent node = 100, minimum number of cases in child node = 50, minimum improvement = 0.0001). To estimate the tree's predictive accuracy and model fit, the risk estimate was calculated. The risk estimate was 0.331, which means that the teaching and learning practices listed in the nodes of the model could accurately predict student confidence for 66.9% of the cases.

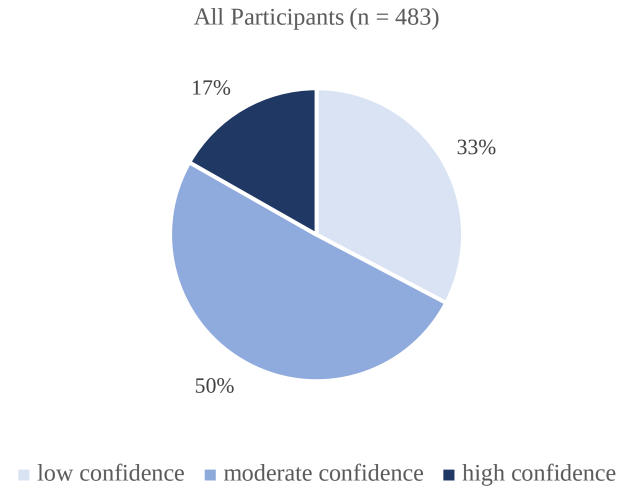
Qualitative data were analysed using NVivo 12 Pro. The transcribed focus group interview involved three cycles of coding: open coding, axial coding, and selective coding. The focus group participants were attribute coded on age, study field, and generational status.

4. FINDINGS

4.1 RQ 1: SELF-EFFICACY x STUDENT PROFILE

Students (n = 483) completed the self-efficacy questionnaire adapted from Han and colleagues (2021) at the beginning (weeks 2, 3, and 4) of the semester. Survey participants were asked to indicate their confidence on a 4-point scale (1 - not at all confident, 2 - somewhat confident, 3 - mostly confident, 4 - completely confident). Students were asked to express their confidence to understand the most difficult concepts, master the skills, do well on the assignments, and do well on exams in their classes. Due to a very low number of ‘not at all confident’ responses, categories ‘not at all confident’ (4-5/16 total points on the self-efficacy scale) and ‘somewhat confident’ (6-9/16) were collapsed into a ‘low confidence’ category (4-9/16). Categories ‘mostly confident’ (10-13/16 points) and ‘completely confident’ (14-16/16) were renamed ‘moderate confidence’, and ‘high confidence’, respectively. The cumulative results of student answers to the self-efficacy survey are illustrated in Figure 1.

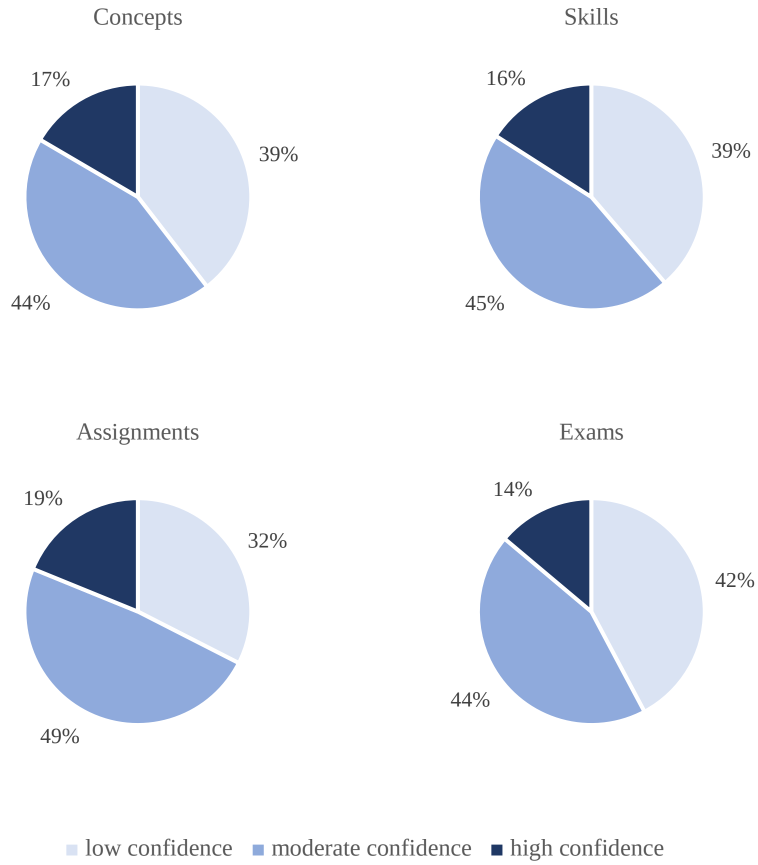
Figure 1. Results of the Self-Efficacy Survey (n = 483)



On average, the survey participants were rather confident. The mean self-efficacy score among all participants was 10.94 (SD = 2.702), and most students (50%) fell into the moderate confidence category.

In regard to the individual items on the self-efficacy survey, students displayed the highest confidence in their capability to do well on continual assessment tasks, and the lowest confidence in their capability to do well on exams (Figure 2). Student self-efficacy towards understanding the most difficult concepts and mastering the skills taught in their classes was approximately the same.

Figure 2. Results of the Self-Efficacy Survey: Individual Survey Items (n = 483)

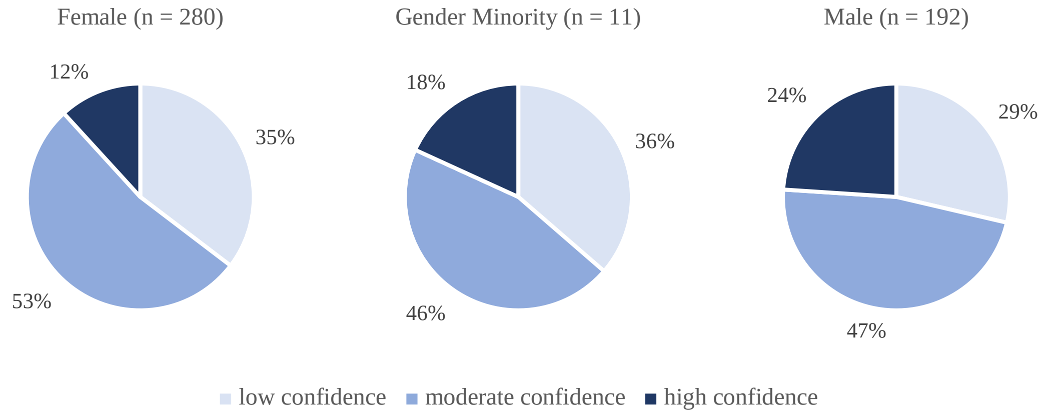


4.1.1 Student Demographics x Self-Efficacy

Gender

In accordance with previous research on self-efficacy in STEM university courses, this study found that female students scored lowest on the self-efficacy scale (M = 10.65, SD = 2.543), while male students scored highest (M= 11.36, SD = 2.830). Gender minority students were more confident than female students but less confident than male students, scoring almost perfectly in the middle between the other two groups (M = 11.0, SD = 3.578). The standard deviation of 3.578 in the scores of gender minority students revealed that the confidence beliefs were largely inconsistent within the gender minority group. Among the three gender groups, male students had the lowest proportion of low-confidence students, while in the gender-minority group, the least students fell into the high-confidence category (Figure 3).

Figure 3. Results of the Self-Efficacy Survey: Gender (n = 483)



The low confidence for STEM fields among female students is widely acknowledged (Cwik & Singh, 2021; Zander et al., 2020). Research exploring the academic functioning of gender minority students, however, has been sparse. A study exploring the performance of secondary school students found that, while gender-diverse students, as a group, had an increased chance of course failure and a reduced chance of taking an advanced math course in comparison to cisgender students, only binary transgender and gender-unsure students were at an educational disadvantage and non-binary students' attainment was on par with that of the cisgender students (Wilkinson et al., 2021). This indicates that the educational experiences of gender minority students vary greatly based on their individual profiles, which could explain the large differences in self-efficacy levels among the gender minority students in this study.

The gender variable and self-efficacy category variable had 3 values each. With gender being a nominal and self-efficacy an ordinal variable, the common statistical procedure when trying to analyse the relationship between the variables would have been to use the cross-tabulation method to establish if there is a significant relationship by looking at the number of expected cases, measuring the statistical significance of the relationship by performing the chi-square test, and measuring the effect size (Phi (φ)/Cramer's V (V)). However, the chi-square test could not be performed with these two variables, due to too many cells having less than five expected cases. In order to eliminate missing cells, values within the gender variable were regrouped into two categories (female and gender minority, and male) based on the observed differences in mean SE scores. A statistically significant difference in confidence level was found between the combined category of female and gender minority students, and male students (x^2 (2, n=483) = 12.044, p = 0.002, φ = 0.158).

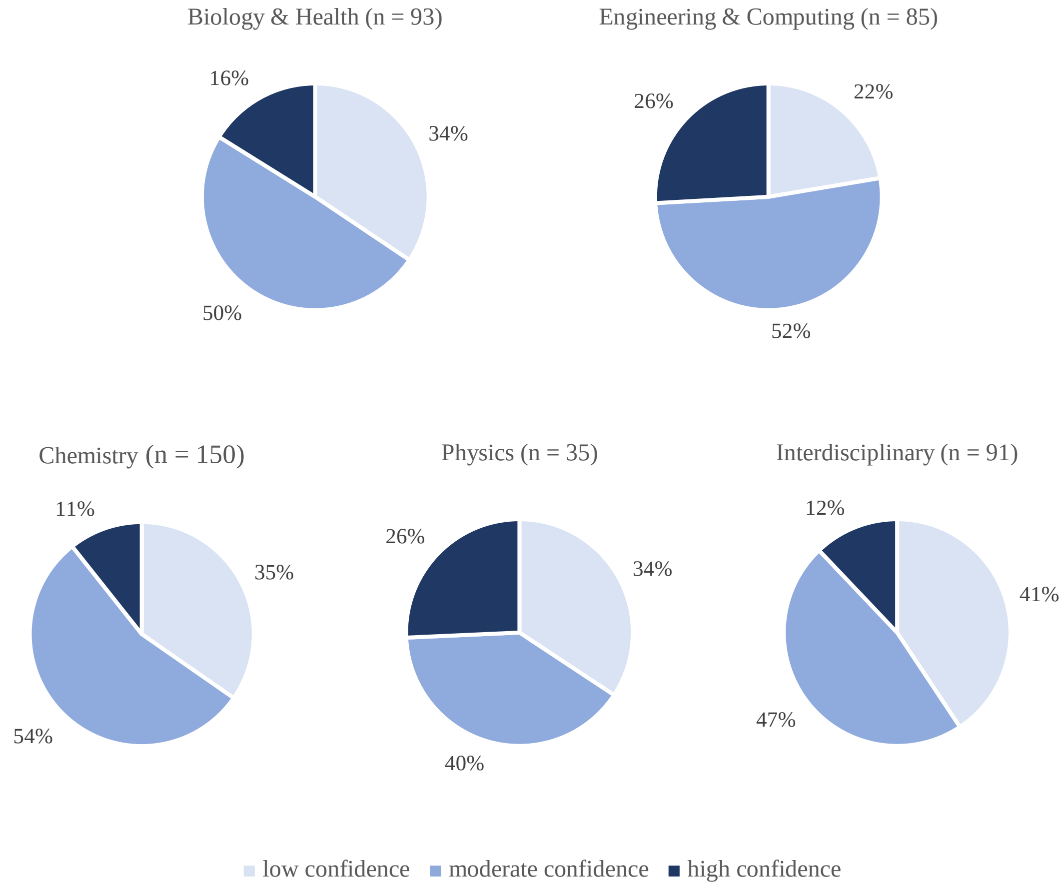
Gender x Study Field

Self-efficacy is known to affect students' academic choices, including the selection of study programmes, and student self-efficacy towards particular study fields is often gender-dependent (Han et al., 2021). Therefore, it was important to investigate the patterns between self-efficacy, gender, and study field in this study as well.

Students from 26 different study programmes participated in the survey. The study programmes were categorised into 5 broad fields: biology and health, engineering and computing, chemistry, physics, and interdisciplinary[3]. Interestingly, students in engineering and computing programmes had the highest self-efficacy (M = 11.52, SD = 2.693), with only 22% of students falling into the low confidence category (Figure 4). Students in interdisciplinary programmes had the lowest self-efficacy (M = 10.42, SD = 2.582), with 41% of students in this group being in the low confidence category. The observed relationship between study field and student self-efficacy was statistically significant (x^2 (8, n = 454) = 16.892, p = 0.031, φ = 0.193).

[3] Interdisciplinary study programmes encompassed various programmes, including Science, Clinical Measurement Science, and Science with Nanotechnology.

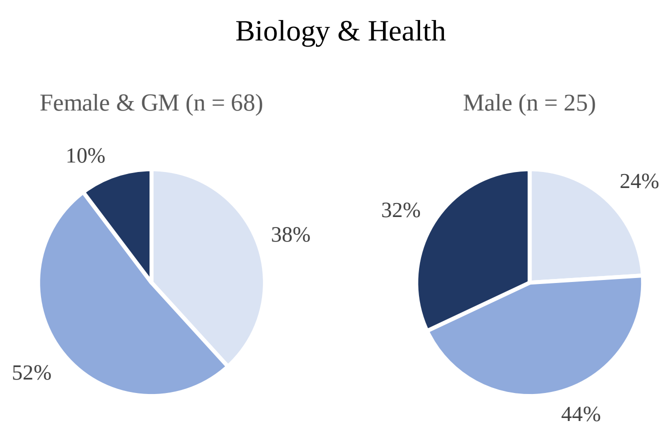
Figure 4. Results of the Self-Efficacy Survey: Study Field (n = 454)



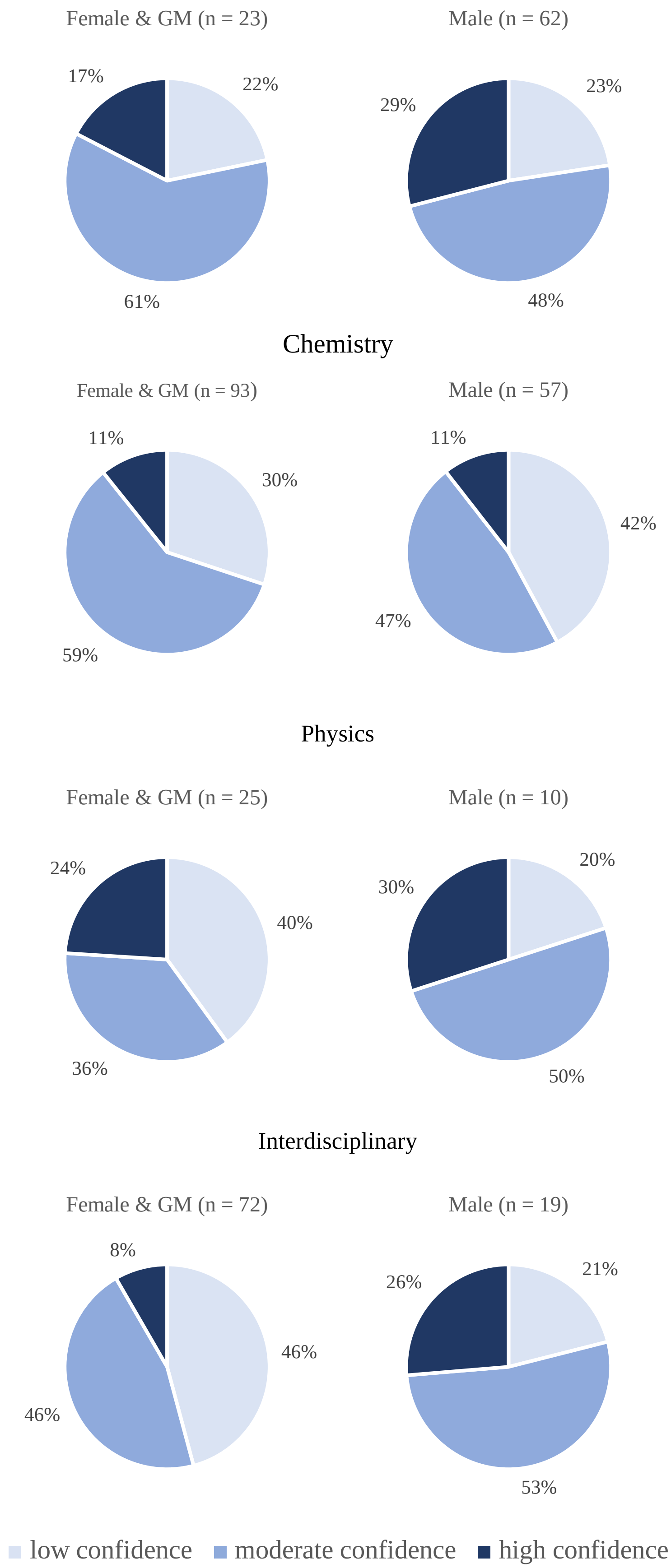
When analysed by gender, some interesting discrepancies were observed between the self-efficacy of male, and female and gender minority students. More male students fell into the high confidence category in all study fields except chemistry (Figure 5). The starkest differences between the gender groups were observed in the fields of biology and health sciences, and interdisciplinary sciences.

It is important to keep in mind that the self-efficacy questionnaire used in this study measured student self-efficacy towards specific classes rather than their study programmes and thus the findings represented in Figure 5 cannot be interpreted as student self-efficacy towards their study fields. However, they do help illustrate the gender-dependent differences in class-specific self-efficacy depending on the study field. The lower self-efficacy scores among female and gender minority students in the field of interdisciplinary sciences were expected since most of the study programmes included within the field belonged to the School of Physics, and physics is a discipline associated with some of the most pervasive gender stereotypes (Cwik & Singh, 2021; Leslie et al., 2015). The significantly lower percentage of confident female and gender-minority students in the field of biology and health, however, was surprising, considering that, across Europe, gender distribution in undergraduate programmes within those fields tends to be fairly even, sometimes with women students being overrepresented (European Commission, 2021). A possible explanation for this might be that female and gender minority biology and health students in the sample had specifically low self-efficacy towards the classes in which their self-efficacy was measured. However, biology and health students were present in a variety of classes where self-efficacy questionnaires were administered, including physics, computing and digital skills, and biology classes, and lower self-efficacy scores among women and gender minority students in this group were observable in all classes, except for one computing and digital skills class.

Figure 5. Results of the Self-Efficacy Survey: Study Field x Gender (n = 454)



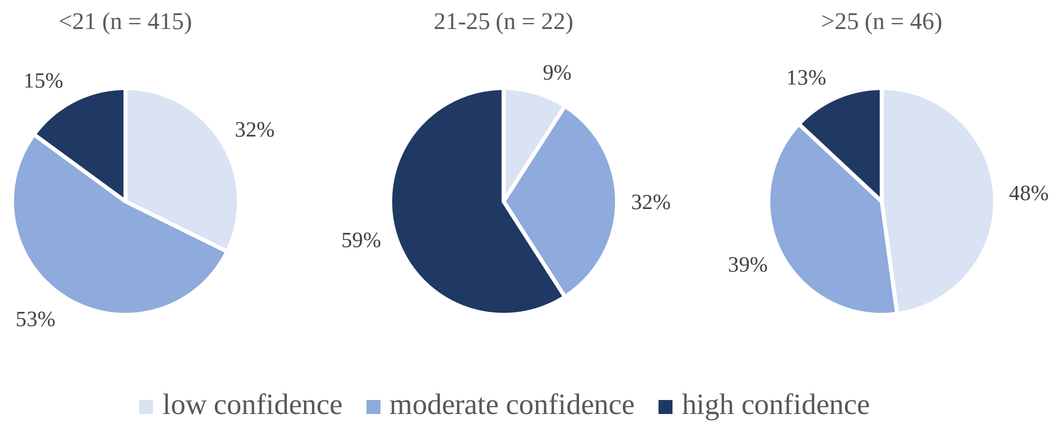
Engineering & Computing


Female & GM (n = 23)
Male (n = 62)
17%
22%
61%
29%
23%
48%
Chemistry
Female & GM (n = 93)
Male (n = 57)
11%
30%
59%
11%
42%
47%
Physics
Female & GM (n = 25)
Male (n = 10)
24%
40%
36%
30%
20%
50%
Interdisciplinary
Female & GM (n = 72)
Male (n = 19)
8%
46%
46%
26%
21%
53%
low confidence
moderate confidence
high confidence

Age

This study has observed some interesting deviations in self-efficacy based on student age, although no statistically significant difference in confidence level was found between the three different age groups ($\tau b = 0.026$, $p = 0.546$). Previous studies found that there were significant differences in self-efficacy beliefs between traditional age and mature students, with mature students reporting greater confidence (Erb & Drysdale, 2017). Erb & Drysdale (2017) observed higher confidence among both maturity groups: young mature (21-24 years) and mature students (25 and above). While in this study young mature students were one of the most confident groups among all participants ($M = 13.59$, $SD = 2.720$), mature students were found to have rather low confidence beliefs ($M = 10.22$, $SD = 2.585$), scoring lower than traditional-age students ($M = 10.88$, $SD = 3.047$). Mature students had the biggest share (48%) of low-confidence students among all age groups (Figure 6). Unlike Erb & Drysdale's study, which focused on the self-efficacy beliefs of students in both STEM and humanities subjects, this study explored the confidence beliefs of STEM students only. In STEM subjects specifically, mature learners have been found to have significantly lower self-efficacy. For instance, Jameson and Fusco (2014) found that learners who had been classified as mature based on either their age (25 and above) or characteristics had lower levels of overall mathematics self-efficacy and higher levels of math anxiety in comparison to traditional students. It might be that while young mature students have more experience, and, often, more motivation to pursue their degree due to having clearer academic and professional ambitions, mature students in undergraduate sciences struggle with self-confidence due to a possibly longer break since their last experience of formal education.

Figure 6. Results of the Self-Efficacy Survey: Age (n = 483)

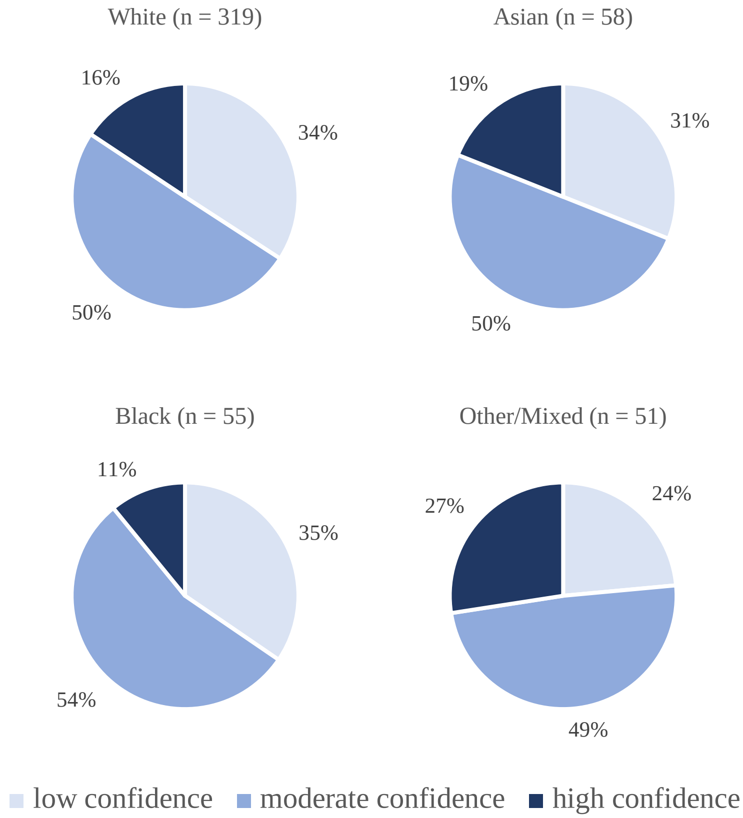


Race/Ethnicity

Self-efficacy survey participants could choose from the following options when providing information about their race/ethnicity: white, black, Asian, Latin American, Middle Eastern and North African, Romani and Irish Traveller, and other or mixed background. 66% of the survey participants were white (n = 366), 12% were Asian (n = 58), 11.4% were black (n = 55), and 5.8% were other race or ethnicity or mixed background (n = 28). With each of the other values representing less than 5% of the survey participants, categories ‘Latin American’, ‘Middle Eastern and North African’, and ‘Romani and Irish Traveller’ were collapsed into ‘other/mixed’, resulting in 51 students (10.6%) in this group.

Black students scored lowest on the self-efficacy scale (M = 10.27, SD = 3.082), white (M = 10.91, SD = 2.646) and Asian students (M = 11.02, SD = 2.572) scored similarly, and other race/ethnicity or mixed background students scored highest (M = 11.76, SD = 2.620). Other race/ethnicity and mixed background students had the largest share of high-confidence students (27%) and the lowest share of low-confidence students (24%) among the 4 race/ethnicity groups (Figure 7). No statistically significant difference in confidence level was found between the groups (x^2 (6, n = 483) = 6.830, p = 0.337, φ = 0.119).

Figure 7. Results of the Self-Efficacy Survey: Race (n = 483)



The low self-efficacy results of black students were anticipated based on previous research. Previous studies found that black students in undergraduate STEM programmes are more vulnerable to low self-efficacy beliefs than their white peers, often as a result of observed inequalities in higher education (Greaves et al., 2022). A recent study found that universities in Ireland are not inclusive enough, observing inequalities in curricula and pedagogical practice and finding that black and minority ethnic students in Ireland are prone to experiencing racial microaggressions from their instructors and peers (Darby, 2022). It might be that the lower self-efficacy beliefs of black students in this sample were affected by observed racial inequalities as well.

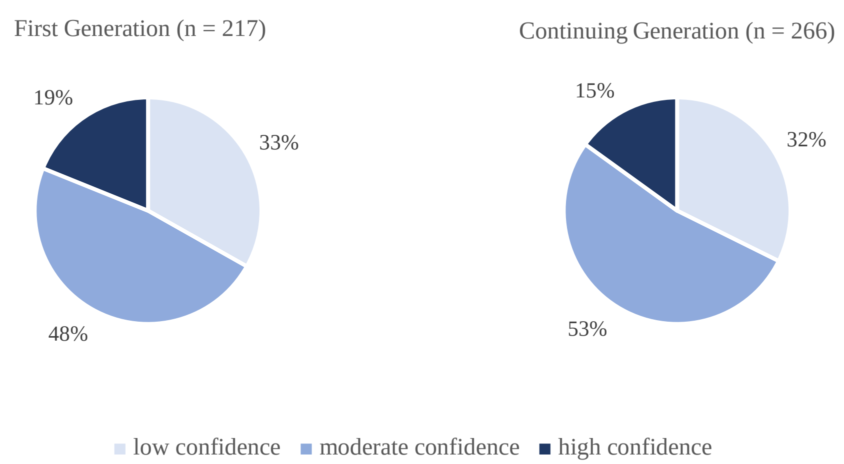
The fact that Asian students were on par with white students in regard to self-efficacy was also unsurprising. Certain Asian nationalities in Ireland have been identified as some of the highest-educated groups (Central Statistics Office, 2016). Non-Irish Asian people have been found to be treated similarly to white Irish in the labour market, while people belonging to the Irish-Asian group have been found to be in an advantaged occupational position in comparison to white Irish people (McGinnity et al., 2018). These findings might indicate that Asians are well represented in the academic and professional environments in Ireland, which might affect student self-efficacy beliefs. US American studies often identify Asian students as majority-ethnic students who outperform students from minority ethnic groups (Kalender et al., 2017; Whitcomb & Singh, 2021) and report that Asian students have the highest self-confidence among all racial groups in particular STEM contexts (Kalender et al., 2017).

The exceptionally high self-efficacy scores among other race/ethnicity and mixed background students were unexpected. Previous intersectional studies have revealed that racial/ethnic inequalities have the highest effect on student confidence beliefs when they intersect with gender (Idahosa & Mkhize, 2021), thus, the high self-efficacy scores could be explained if the majority of the students in this group would have been male. However, the majority (60.8%) of the students in other race/ethnicity and mixed background group were female. Other studies found that race/ethnicity has the strongest (negative) effect on student confidence beliefs when they intersect with socio-economic inequalities (Hood et al., 2020). Students in the other race/ethnicity and mixed background group were primarily continuing-generation students (62.7%). Therefore, it might be that the effects of belonging to a racial/ethnic minority group among these students were mediated by their socio-economic status, although no statistically significant differences on account of generational status were observed among the students in this study.

Socio-Economic Background

On average, first-generation students had slightly higher scores on the self-efficacy survey (M= 11.0, SD = 2.734) than continuing-generation students (M = 10.89, SD = 2.681) and the results of the previous studies indicating lower overall self-efficacy scores among first-generation students could not be replicated in this study. The first-generation student group also had a larger share of high-confidence students (Figure 8). No statistically significant difference in confidence level (low/moderate/high) was found between the two groups (x^2 (2, n = 483) = 1.610, p = 0.447, φ = 0.058).

Figure 8. Results of the Self-Efficacy Survey: Generational Status (n = 483)



Double and Multiple-Minority Status

When comparing all 4 demographic modifiers of self-efficacy, maturity (>25) stood out as a very impactful factor. Combined with certain other minority statuses, it produced some of the lowest self-efficacy scores overall, even with students belonging to majority groups otherwise. For example, white male first-generation students who were over 25 and continuing-generation female and gender-minority students over 25 had some of the lowest self-efficacy scores overall (M= 9.0 and 9.29, respectively) (Table 2). The combination of racial minority and first-generation statuses also produced low scores for some racial minority groups, with black first-generation students scoring low, despite being in the otherwise overall confident 'male' and '<21' groups (M = 9.43). In the only other very low-scoring group, a combination of 3 minority statuses could be observed, with first-generation black female and gender-minority students under the age of 21 having the second lowest score among all groups (M = 9.42)[4].

Table 2. Comparison of Mean Self-Efficacy Scores Among Different Student Groups

Self-Efficacy x Gender x Age x Race x Generation

Gender	*Age*	*Race*	*Generational Status*	Mean	N	Std. Deviation
Female and Gender Minority	<21	White	First Generation	11.13	70	2.576
			Continuing Generation	10.51	96	2.551
		Black	First Generation	9.42	12	2.392
			Continuing Generation	10.53	17	2.401
		Asian	First Generation	10.14	7	3.237
			Continuing Generation	11.00	27	2.631
		Other	First Generation	10.67	9	2.398
			Continuing Generation	11.10	20	2.918
	>25	White	First Generation	10.50	12	2.195
			Continuing Generation	9.29	7	1.704
Male	<21	White	First Generation	11.20	60	2.730
			Continuing Generation	10.92	49	2.262
		Black	First Generation	9.43	7	1.618
			Continuing Generation	10.50	8	4.629
		Asian	Continuing Generation	11.27	15	2.154
		Other	First Generation	12.40	5	1.517
			Continuing Generation	12.67	9	1.732
	21-25	White	First Generation	13.40	5	2.966
			Continuing Generation	14.80	5	2.683
	>25	White	First Generation	9.00	11	3.098

4.1.2 Past Performance x Self-Efficacy

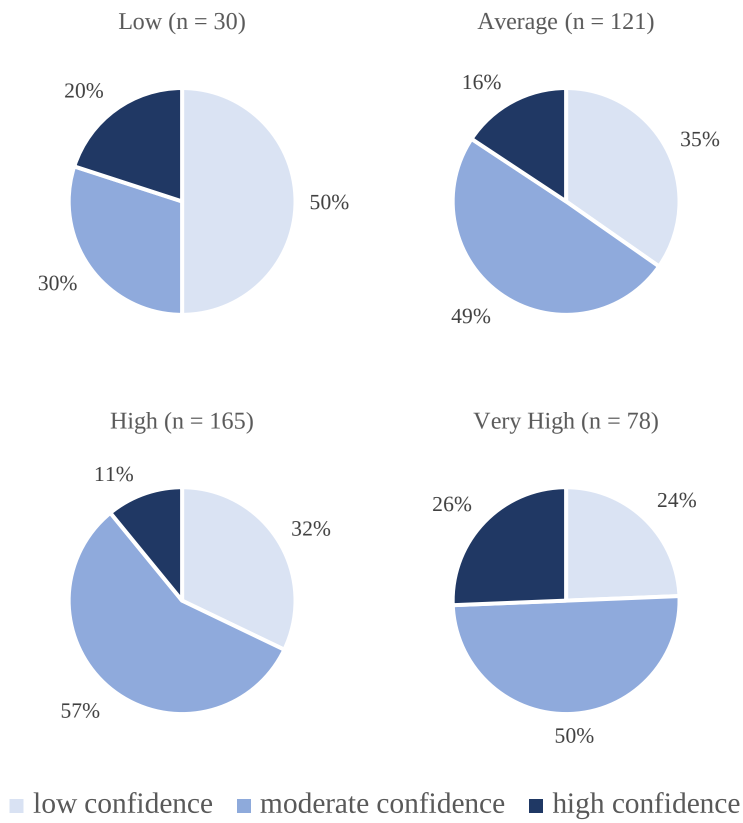
In order to explore how student self-efficacy is influenced by their past performance, students were asked to indicate their Leaving Certificate results when filling in the demographic survey preceding the self-efficacy questionnaire. The item 'Irish Leaving Certificate points

[4] Trends are reported on groups containing at least 5 students.

(if applicable)’ received the scarcest responses among all items on the survey. There were multiple reasons for this, such as students completing their secondary education abroad, following alternative paths to university education (e.g., having studied at a further education institution), or having graduated before Leaving Certificate points were introduced. Other students could not remember the points they received or could only remember them approximately. Most missing responses, however, did not include specifications for why the students chose not to respond. Performance is generally a sensitive topic, and thus it is typical that some of the students, especially the lower-achieving ones, choose not to respond.

In order to utilise as many responses as possible and to include those indicating an approximate number of points in the analysis, student answers were binned into 4 performance categories: ‘very high’ (>525 points), ‘high’ (426-525 points), ‘average’ (326-425 points), and ‘low’ (<326 points). This resulted in 394 valid responses. A clear indication of an association between previous performance and academic self-efficacy could be observed in the student responses. The low-performing student group had the largest share (50%) of low-confidence students, while the very-high-performing group had the lowest share (24%) of low-confidence students and the highest share (26%) of high-confidence students (Figure 9). The positive association between previous performance and student self-efficacy, although weak, was statistically significant ($\tau b = 0.096$, $p = 0.031$).

Figure 9. Results of the Self-Efficacy Survey: Past Performance (n = 394)



4.2 RQ 2: SELF-EFFICACY x PEDAGOGICAL PRACTICE

4.2.1 Class Observations

15 class observations were performed in total. Observed classes included the following subjects: physics (n = 3), computing and digital skills (n = 3), engineering (n=2), biology (n = 3), chemistry (n = 2), and mathematics (n =2). The means of student self-efficacy scores are compared with regard to class characteristics (Table 2).

Table 2. Self-Efficacy Means: Class Type, Class Size, Instruction Week, Subject

Self-Efficacy: Means		Mean	N	Std. Deviation
Class type	Lecture	11.00	375	2.720
	Laboratory	10.46	84	2.539
	Tutorial	11.58	24	2.858

Class size	1-40	10.42	104	2.538
	41-70	10.88	133	2.666
	>70	11.19	246	2.767
Instruction week	2	12.14	80	2.690
	3	10.81	221	2.638
	4	10.57	182	2.654

Students seemed least confident in a laboratory setting, although class type had no significant correlation with student self-efficacy (x^2 (4, n = 483) = 6.382, p = 0.172, φ = 0.115). Students were also most confident in high-attendance classes and there was a weak positive association between class size and student self-efficacy (τb = 0.083, p = 0.045). A decline in mean self-efficacy scores could be observed as the semester progressed, with students scoring lowest on the 4th week of instruction: a medium strength negative association was found between instruction week and student self-efficacy (τb = -0.156, $p<0.001$).

Classroom Practices

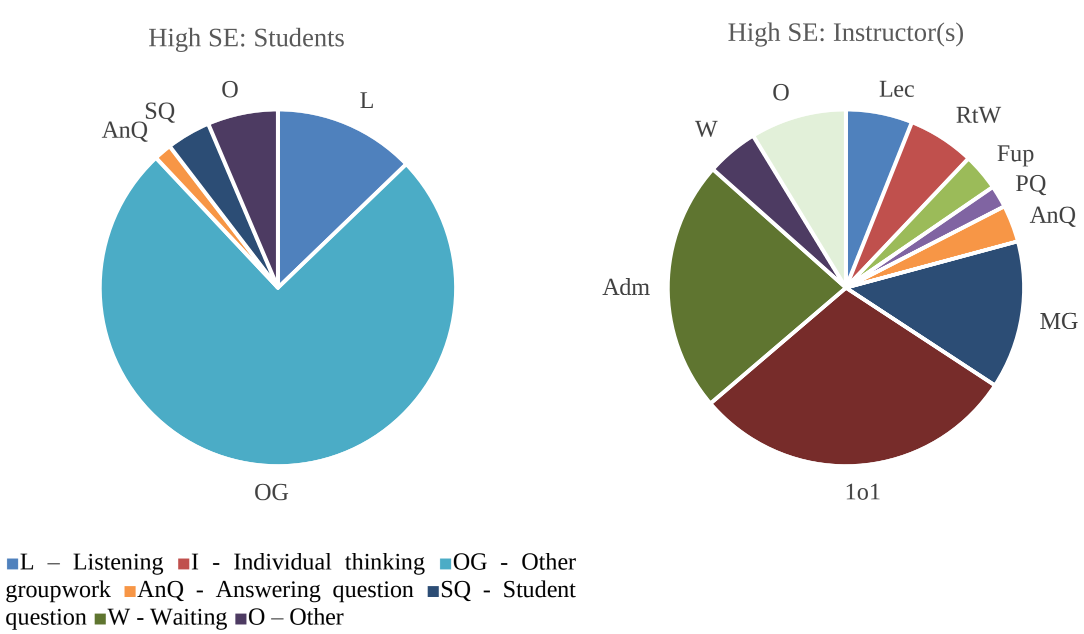
The observational data collected was compared with the self-efficacy questionnaire results for each class. In order to be able to explore how well the instructional practices employed in each of the observed classes work for the majority of the students, classes were compared by the percentage of students in the 'low confidence' category.

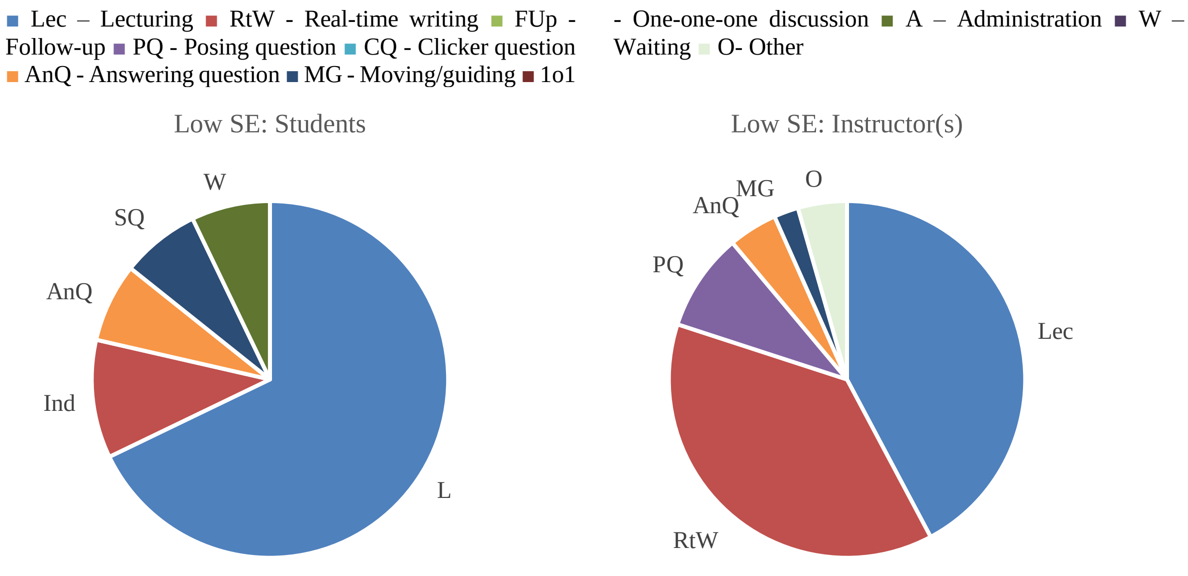
Practice-based classes

In practice-based classes (laboratories/tutorials), many more students fell into the 'low confidence' category if the structure of the class resembled a lecture. The classroom activities for the laboratories and the tutorials with the highest and lowest numbers of low-confidence students are presented in Figure 10 and Figure 11. The laboratory with the lowest share of low-confidence students (15%) was primarily based on group work (students were engaged in group work for 91% of the class). The instructor, although engaged in some administrative tasks, offered a wide range of support to students, including extended one-on-one discussions.

The laboratory with the most (63%) low-confidence students primarily focused on lecturing and real-time writing as means of instruction. The students were listening/taking notes for the majority (90%) of the class. The students engaged in some tasks requiring individual thinking (the student code 'individual thinking' (Ind) was present for 14% of the class), but these were not followed up by instructor feedback. The instructor was moving around the class (MG) for 5% of the class, which meant minimal supervision offered on individual tasks. While there was some communication between the students and the instructor in this class, not a single instance of one-on-one discussion was recorded.

Figure 10. A Comparison of the Prevalence of Codes in High and Low-Efficacy Laboratories

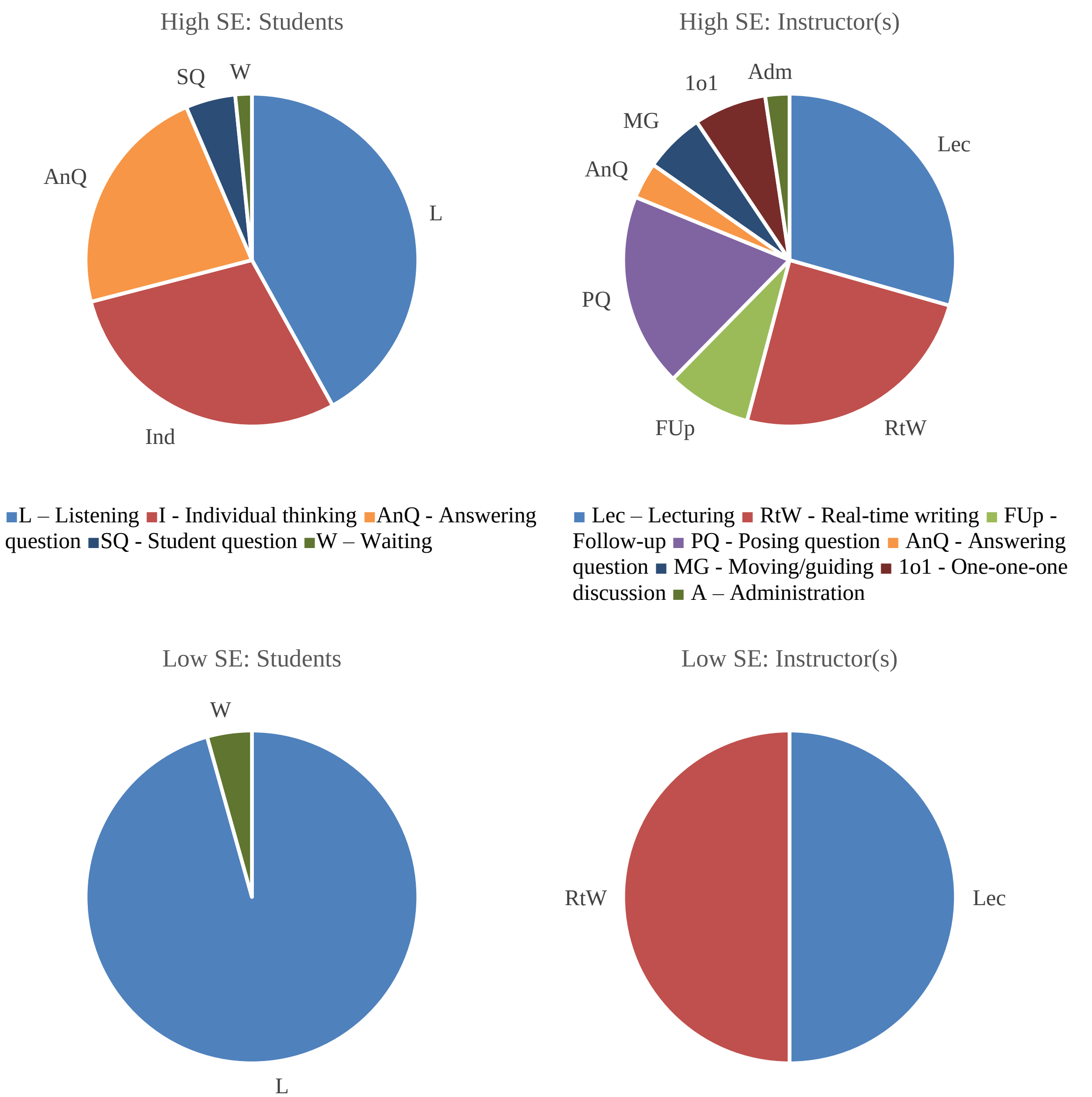




Student confidence in tutorial classes was also highly reliant on how interactive the class was. The tutorial with the lowest percentage (20%) of low-confidence students, while involving a significant amount of lecturing (Lec), provided students with many individual thinking opportunities (Ind). Student-instructor interactions in this tutorial were ample with the instructor code 'posing questions' (PQ) present for 59% of the class and the student code 'answering questions' (AnQ) present for 52% of the class. Individual thinking tasks were supervised (the instructor code 'moving and guiding' (MG) was present for 19% of the class) and followed up by instructor feedback (the instructor code 'follow-up' (FUp) was present for 26% of the class). Students received individual attention on tasks requiring individual thinking (the student code 'one-on-one discussion' (1on1) was present for 22% of the class).

The tutorial with the highest percentage of low-confidence students (50%) stood out as extremely non-interactive. 'Lecturing' (Lec) and 'real-time writing' (RtW) were the only instructor codes used when observing this tutorial. The students in this class were engaged in listening and taking notes (L) for the majority of the class time. Not a single (non-rhetorical) student-instructor interaction regarding the class topic was observed.

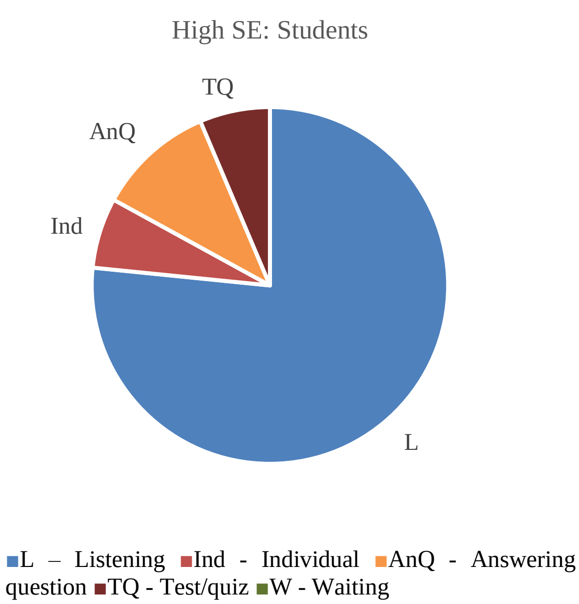
Figure 11. A Comparison of the Prevalence of Codes in High and Low-Efficacy Tutorials

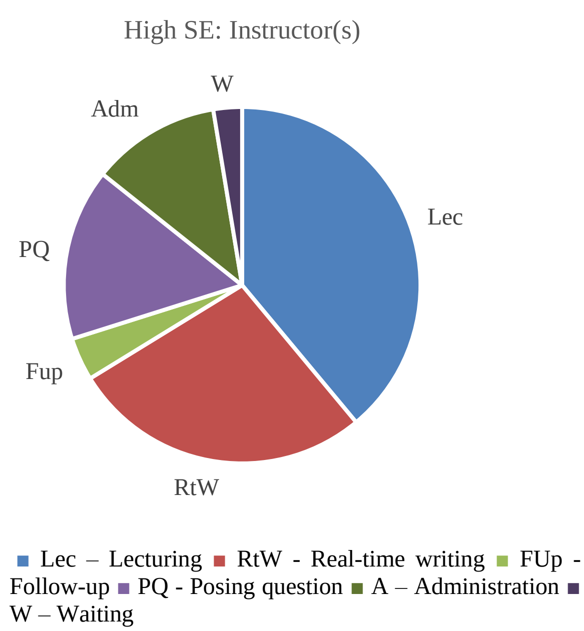


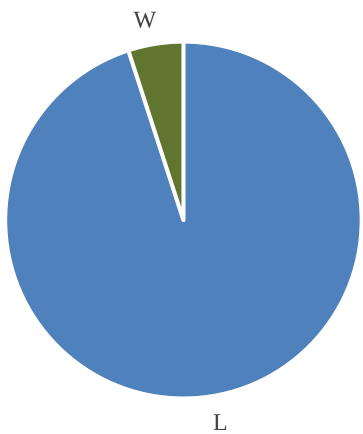
Lectures

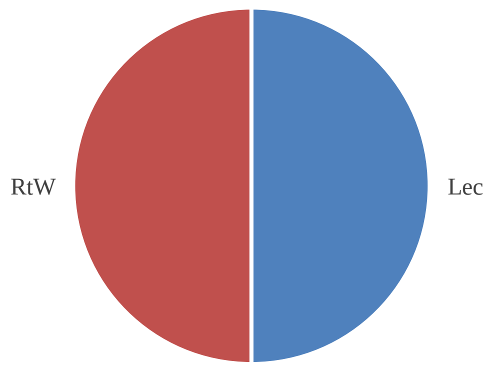
The results of the observations in lectures were less straightforward. Interestingly, the lecture with the highest and the lowest number of low-confidence students were in the same subject of computing and digital skills. In these lectures, employment of active learning approaches and student-instructor interaction seemed to be of vital importance. In the lecture with the lowest percentage (18%) of low-confidence students, students were asked to apply the material learnt in class to practice by completing an individual assignment (student code ‘individual thinking’ (Ind) was present for 8% of the class time) in the middle of the lecture and a quiz (student code ‘test or quiz’ (TQ) was present for 8% of the class time) before the end of the class (Figure 12). Both the individual assignment and the quiz were followed up with instructor feedback (instructor code ‘follow-up’ (FUp) was present for 8% of the class duration). The instances of student-instructor interaction in this class involved instructor questions (instructor code ‘posing question’ (PQ) was present for 30% of the class time) and student answers (student code ‘answering question’ (AnQ) was present for 13% of the class time). Although this lecturer primarily relied on lecturing as an instructional approach (instructor code ‘lecturing’ (Lec) was present for 75% and ‘real-time writing’ (RtW) was present for 53% of the class time), it seems that any use of student-centred practices made a notable difference to student self-efficacy in lectures concerning computing and digital skills in this study. In comparison, the computing and digital skills lecture that did not involve active learning and had no recorded instances of (non-rhetorical) student-instructor interaction, had a much higher percentage of low-confidence students (50%).

Figure 12. A Comparison of the Prevalence of Codes in High and Low-Efficacy Lectures



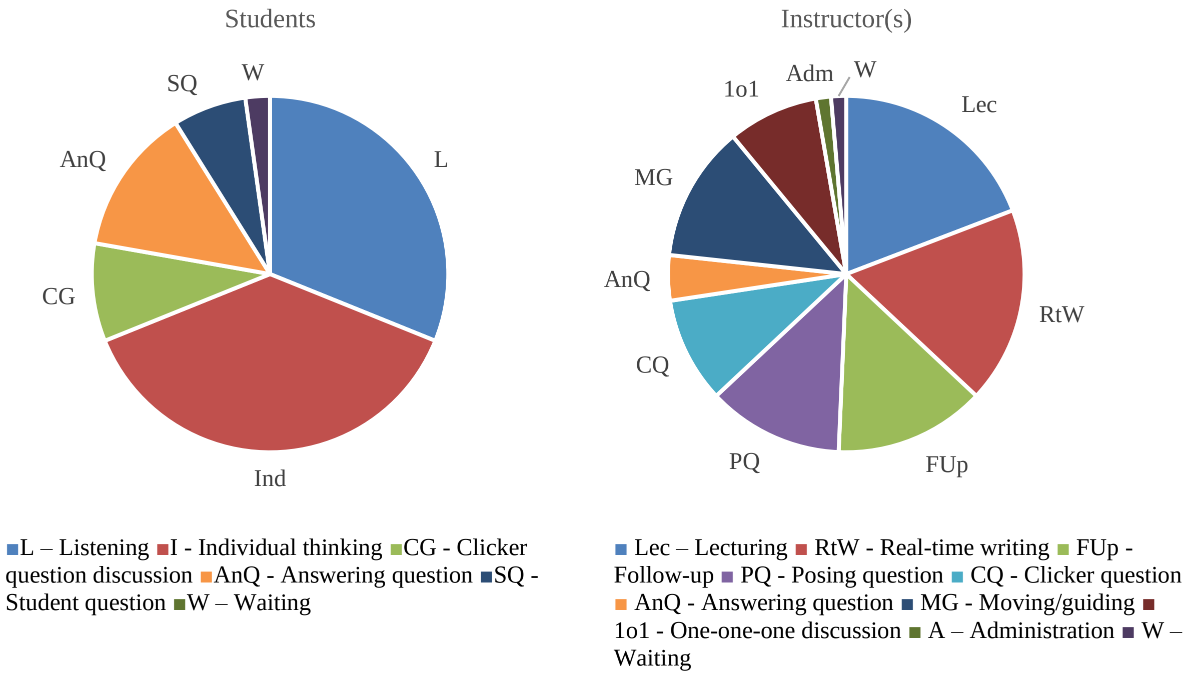






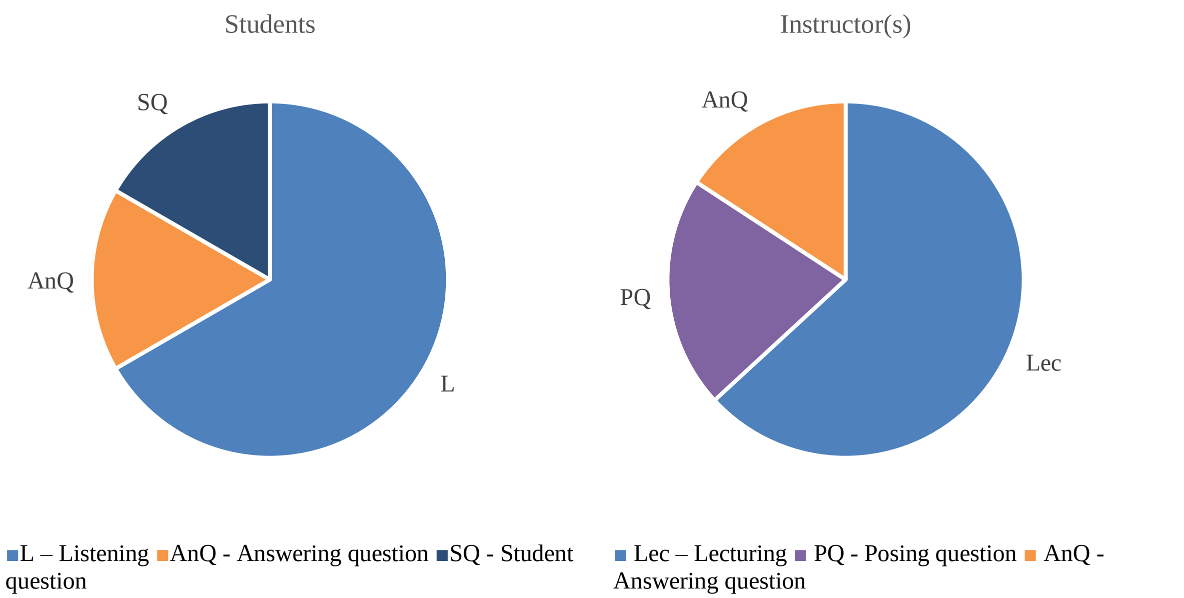
Surprisingly, the lecture with the second highest number of low-confidence students (47%) was a high-engagement student-centred physics class (Figure 13). Three focus group participants identified this lecture as their favourite class. They described their instructor as "really interactive" and found that engaging with instructional material prior to the lecture and answering clicker questions in class helped them understand the content better. It might be that the low self-efficacy scores in this lecture had to do with the subject matter. Physics has been identified as one of the STEM disciplines associated with the highest ability beliefs (Leslie et al., 2015) and, according to the instructor, most students in this class have not had previous instruction in physics. The general attitude towards physics being difficult and requiring high innate ability and not having previous experience in physics might have affected the self-efficacy scores in this class negatively, regardless of the instructional methods applied. In addition, the majority (70%) of the survey participants in this class were women. Gender-based differences in self-efficacy have often been observed in introductory physics courses (Lindstrøm & Sharma, 2011; Marshman et al., 2018) and women's low self-perceptions in physics have been found to be extremely persistent (Bottomley et al., 2023; Cwik & Singh, 2021). Therefore, it is also possible that the low mean of self-efficacy scores in this class reflected some of the general gender-related trends in physics self-efficacy rather than the effects of pedagogical practice. On the other hand, the high number of active-learning tasks could have negatively affected student confidence in this class. Active learning pedagogies have often been linked to increased anxiety in science courses (Geiger & Cooper, 1995) and it might be that the students in this class found active learning tasks especially stressful due to not having any previous experience in physics.

Figure 13. The Prevalence of Codes in a Low Self-Efficacy Lecture: Physics



The lecture that had the second lowest percentage (24%) of low self-efficacy students was surprisingly instructor-centred. 'Lecturing' (Lec) was the predominant code used to record instructor activities in this class (Figure 14). Research has shown that women tend to have higher self-efficacy for biology than other sciences, with there being no significant differences in self-efficacy between female and male students (Uitto, 2014). A student in the focus group described this class as being "pretty straightforward," which might indicate that for classes which are perceived as less difficult, the traditional lecture format might be sufficient in facilitating student learning, which could influence student self-efficacy positively. It must also be noted that student engagement in this class was high. The lecturer in this class posed multiple questions (instructor code 'posing question' (PQ) was present for 32% of the class) and received multiple answers from the students each time (student code 'answering question' (AnQ) was present for 24% of the class). The students were inquisitive and felt comfortable asking questions throughout the lecture (not only when prompted) (student code ‘student question’ (SQ) was present for 24% of the class). Therefore, the high self-efficacy scores in this class might be the result of student-instructor communication.

Figure 14. The Prevalence of Codes in a High Self-Efficacy Lecture: Biology



Classroom Practice x Self-Efficacy

Pedagogical practices within the observed lectures underwent further investigation through the application of the decision tree method to the data collected. Depending on student answers to items on the self-efficacy questionnaire, students were divided into categories of ‘not confident’ (4-9/16 points) and ‘confident’ (10-16/16 points). These categories were selected in an attempt to divide the survey participants into a high and a low-risk group in regard to potential disengagement and attrition from STEM courses. The analysis produced 7 nodes (minimum number of cases in parent node = 100, minimum number of cases in child node = 50, minimum improvement = 0.0001). Gains for each node are represented in Table 3. Two student codes (waiting and individual thinking/problem solving) and one instructor code (real-time writing) helped predict the category of student confidence (Figure 16).

Table 3. Gains for Nodes

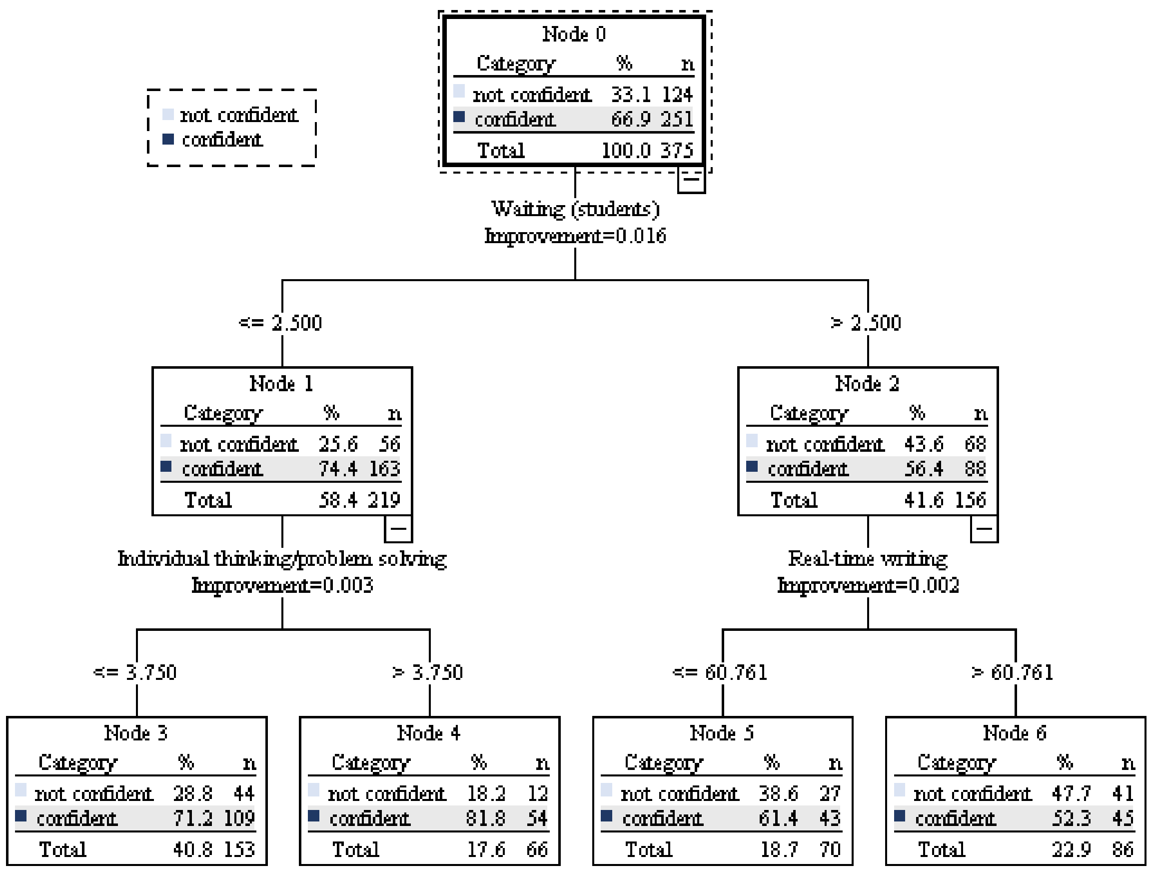
Gains for Nodes

(target category: confident)

	Node		*Gain*			
Node	N	Per cent	N	Per cent	Response	Index ▼
4	66	17.6%	54	21.5%	81.8%	122.2%
3	153	40.8%	109	43.4%	71.2%	106.4%
5	70	18.7%	43	17.1%	61.4%	91.8%
6	86	22.9%	45	17.9%	52.3%	78.2%

[5]

Figure 15. CRT Analysis: Pedagogy x Student Confidence



[5] Only terminal nodes which represent the best classification predictions are listed in the table.

In instances where the student code ‘waiting’ (instructor late, working on fixing AV problems, instructor otherwise occupied, etc.) exhibited minimal presence (≤2.5% of the class), students were predicted to be much more confident than in classes where the students had to wait more, signifying that the effective utilisation of class time significantly influences student confidence in this study. In classes where the students waited less, individual thinking/problem solving activities could also predict student confidence. Low prevalence of the individual thinking/problem solving code (≤3.75%) could predict lower percentage of confident students. The use of individual thinking/problem solving activities in the classroom could predict the highest percentage of confident students (Table 3). In classes where student code waiting was more prevalent (>2.5%), the prevalence of the instructor code ‘real-time writing’ (real-time wiring on board, doc. projector, etc.) was of significance. When ‘real-time writing’ dominated a substantial portion (>60.8%) of the class duration, students were predicted to exhibit significantly lower confidence levels, revealing that students are less likely to hold high confidence beliefs in lectures based on traditional lecturing methods in this study.

4.2.2 Student Accounts

In order to explore how pedagogical practice affects the self-efficacy beliefs of women and gender minority students specifically, a focus group was organised. The invitation to participate in the focus group was only extended to women and gender minority students, and thus no male students were interviewed.

Students in the focus group were asked to provide information concerning their age, generational status, and study programme. The descriptive characteristics of the focus group participants are depicted in Table 4.

Table 4. Characteristics of the Focus Group Participants

Participant classification	*Age*	*Generation*	*Study Field*
Interviewee 1	20	First Generation	Physics
Interviewee 2	19	Continuing Generation	Chemistry
Interviewee 3	20	Continuing Generation	Chemistry
Interviewee 4	20	Continuing Generation	Interdisciplinary
Interviewee 5	19	Continuing Generation	Interdisciplinary
Interviewee 6	18	First Generation	Interdisciplinary
Interviewee 7	20	First Generation	Biology & Health
Interviewee 8	18	First Generation	Biology & Health
Interviewee 9	19	First Generation	Biology & Health
Interviewee 10	18	First Generation	Physics
Interviewee 11	19	Continuing Generation	Physics
Interviewee 12	18	Continuing Generation	Physics
Interviewee 13	17	Continuing Generation	Physics

In agreement with the results of the self-efficacy questionnaires, the students in the focus group made a fairly confident impression overall. Many of them quoted a long-term interest in science as the main factor behind their decision to pursue a STEM degree. While some students described having had “a rough idea” they wanted to study science, others recalled having always been interested in a specific field, such as biology or medicine. In relation to their classes, the students brought up a variety of factors that contributed to their class experience, including interest, prior instruction in the subject, perceived usefulness of the material, instructor characteristics, and specific pedagogical practices in different class settings. Students often spoke about how much they were enjoying their classes, how interesting and engaging they found their classes to be, and how motivated they felt when discussing class-specific self-efficacy. Please refer to Appendix 3 for the map of the main themes identified in the analysis of the focus group interview.

General atmosphere and student-staff relationships

The first impressions about the university influence students’ feelings of belonging, which are strongly related to their self-efficacy (Li & Singh, 2022). There was a general consensus among the focus group participants that the first semester of their study programme had been a positive experience, that they were enjoying their courses and that they felt that the university staff were friendly and approachable. One student compared their experiences at a different university with their first semester here:

> There was a lot of pressure on grades (at the other university). And I did well, I do well, but I just felt that if I did start slipping at any point, it'd kind of be, "Oh, you don't belong here anymore." Whereas here it's kind of more, "Try your best." And then in (the other university), I felt like none of the lecturers wanted to be there, or whatever. So, whenever I approached them with a problem, I was kind of blown off . . . But I came here, and the lecturers are just much more friendly, and they're much more open to speaking. (I3)

A lot of self-efficacy information comes from vicarious experience, and thus, it is especially important for female and gender minority students to feel represented in their environment. I3 pointed out how, in comparison to their previous university, they now had more female instructors, which was a positive thing and, in their words, contributed to the university having "a much nicer atmosphere".

The student comfort in the classroom and how much they enjoyed their classes depended largely on instructor qualities as well. When talking about their favourite classes, the students mentioned the instructors being "nice", "conversational", "patient", "understanding", "engaging", "enthusiastic", and "funny". Students connected such instructor qualities with being able to engage with and understand the class content better. One student pointed out how accessible language in the classroom did not only positively contribute to establishing an equal relationship between the instructor and the students, but also helped them better understand the subject they had not had any previous instruction in:

> But also, the fact that our lecturer— I feel like he's very [pause] conversational. And I like it when lecturers tend to be conversational because you feel like you're on the same level with them and not speaking to someone who's superior to you. And also, it provides a bit better understanding of the subject because, at least for me, because I don't have prior experience, having it in a conversational tone is sort of like the base. And then I'll be able to add the more technical, more accurate terminology. (I2)

Students talked about teacher patience and attentiveness, as well as the thoroughness of instruction in relation to being able to understand difficult concepts, especially in sciences that are notoriously perceived as difficult, such as mathematics and physics. For many, individual attention from the instructor was especially important. I9 mentioned that in her favourite lecture, the lecturer walked around the class helping students on an individual basis, even though it was a large-enrolment lecture in which providing students with individual attention is understandably difficult. Another student pointed out that, in addition to the positive personality traits of the instructor and in-class use of instructional videos, receiving individual attention in high-attendance classes was important because it contributed to them being able to learn effectively:

> I mean, the lecturer [pause] he's very sweet. So, he shows a bunch of videos. It's very, kind of, one-on-one and [pause] yeah, one-on-one. It's like, we're all there, it's a full class but you still feel like you're learning stuff. (I11)

Other students linked teacher charisma and enthusiasm for teaching with being able to engage with the class content and enjoy the class, especially in a lecture setting:

> There's one physics class we have . . . And that lecturer— he's really engaging. He's really enthusiastic and funny. It doesn't feel like a lecture. [Pause] It obviously can be quite [pause] like you just have to sit there in silence and listen, but he is really engaging with the class and making jokes and stuff. So, you're actually paying attention because you're enjoying what you're doing. (I4)

According to the students in the focus group, instructor qualities generally perceived as negative, such as arrogance, or rudeness, have a negative influence on student-staff relationships. I2 recalled instances of patronising behaviour in one of their classes:

> But she (the instructor) has this way, she has this mannerism, where **it's like we're children. And she's like a teacher in a primary school.** The other day, I was taking notes on my phone because I forgot my laptop. And she got mad that some people were on their phone, and I get getting mad [pause] if you're a primary school teacher. **As a lecturer, you're wasting— I think you're wasting more time by telling people, "Hey, get off your phone," this kind of thing**. Or assuming that people are on their phones because they're not paying attention. And rather than just continuing

> with the subject. And just her mannerism, in general, just feels very— that's the kind of lecture I don't like when they feel like they— they need to be superior to us in a way. And I get that there's the— **I'll always respect my lecturers. But when there's this holier than thou attitude [pause] I don't respect.**

Another student pointed out that the way instructors communicated with other students impacted their image: "I think there's a general consensus not many people like her (the instructor) because we think that she's kind of rude to some of the students." (I9) While students agreed that facilitating student-staff communication in a high-attendance setting can be challenging, they felt that being rude to students who are more outspoken and have a tendency to interrupt the instructor with their questions or observations was "not right" (I3). Students pointed out how the lecturers who are less strict about when students and instructors are allowed to interact help them feel more confident about asking questions: "If it's someone who's more flexible, even if it's a big class, sometimes it's just easier to even put your hand up and ask something." (I11) Lack of urgency in addressing student questions or asking the students to address their questions after the class or per e-mail was seen as a negative practice by the participants in the focus group. According to them, individual questions help identify the areas most students are likely to struggle with and should be addressed immediately:

> Just [pause] yesterday, I think, we had that class, and someone put their hand up and asked, and he (the instructor) was like, "Come back to me, I'll do it— I'll talk to you later about that." But it was something that everyone definitely needed to know . . . Because he wasn't really going through anything, either. So, he had the time to explain the question . . . Some people are too nervous, too quiet, too shy, or whatever, to ask the question. So, if someone does ask the question as needed [pause] he kind of puts it off and says, "I'll talk to you individually at the end." But we all want to know the answer. (I11)

Instructors who failed to facilitate effective communication with their students contributed to students' experiences negatively. Students mentioned that instructors who could not engage with the students in an effective manner and were dismissive made them disengage from the class and undermined their motivation to learn, especially in more challenging subjects where students relied on extra support:

> It's like, I can either motivate myself to do it [pause] because the lecturer for that one, he's not really given a lot of material to go off of . . . Where's the point of me trying to put effort in if you're not going to put effort in back? So, because we asked before, "Oh, is there anything else you could do for us? Provide us with more information, whatever?" He was like, "It's up to yourself. I've used up my time." (I5)

Positive student-instructor relationships can contribute to students' self-efficacy both directly (Liu et al., 2021), and by affecting students emotionally (Mazer et al., 2014). Previous studies have found that positive instructor qualities, such as a positive attitude, clear teaching style, and good communication skills helped student-instructor relationships, while lacking clarity, immediacy, and demonstrating poor communication skills caused negative emotional responses among students (Mazer et al., 2014). The responses of the focus group participants replicated those findings, as students described instructor approachability, friendliness, enthusiasm, patience, understanding, and attentiveness as some of the most important instructor qualities that helped student-staff relationships. Previous research suggests that student-instructor relationships are especially important for students from disadvantaged groups (Liu et al., 2021), and academic relationships have been proved to be essential to fostering high self-efficacy beliefs in women in STEM (Zeldin & Pajares, 2000). It is therefore unsurprising that the female and gender minority STEM students in the focus group brought up student-staff relationships as one of the most important factors influencing their academic experiences.

Instructional Practices

Active learning practices were commonly quoted as something that both helped students learn effectively and increased their confidence. In regard to lectures, students mentioned that online quizzes, online labs, instructional videos they were required to watch before class, and in-class use of personal response systems and practice sheets contributed to their learning experiences positively. Students were particularly fond of lectures which utilised instructional scaffolding and active learning and found it easier to learn in those lectures: “I like a lot of my classes but physics, I think, I like better just because he gives us three videos to watch beforehand . . . and in the actual lecture we do practice questions, so it’s really helpful.” (I8) Students found that even though they preferred other classes based on the subject, they found that their favourite classes were the ones that utilised a lot of instructional support. Students also found that instructional scaffolding was especially important in subjects they had no previous instruction in, as well as in subjects that are commonly perceived as more difficult, such as physics and mathematics. Two differential accounts of experiences in mathematics classes help illustrate the difference in student sentiment towards the class. Students in mathematics lectures that utilised quizzes and practice sheets and provided students with examples to mathematics problems helped them understand the content better:

> There’s a lot of, I suppose, support there. So, you have a quiz every week to complete, you’ve got the practice sheets, and stuff, as well, so you can get your knowledge going. And then once, you know, she’ll set it to example, so you can see where it’s all coming in instead of just letting you go through it and giving you theory lessons. (I3)

Students in instructor-centred mathematics lectures felt that the classes did not provide them with the necessary knowledge and were disengaging:

> I think nobody’s — we’re not really enjoying the maths class . . . it’s basic maths, but — I think, for me, anyway, personally, the way I do maths, it’s doing questions . . . I don’t want to know the history of maths. I don’t want to know how this came about. I don’t want to know how that formula came about. It’s more like, “Yeah, these are the questions that will be asked in an exam, and so I need to know— show me how to do it.” Whereas he— he’s very much one of the lecturers that just reads off the slides . . . half the people don’t even show up. (I5)

Lectures are usually the most theory-heavy classes students attend, and the concepts taught in lectures are then practically applied in practice-based classes. However, students pointed out how the ineffectiveness of theory-based instruction can affect their performance in practice-based classes as well:

> when you're given that lecture . . . and you go into a tutorial to put that into practice. Well, you can't really put it into practice if you haven't been properly taught, do you know what I mean? It's hard to put that into practice. (I5)

Students also noted that didactic instruction left them feeling unassured before tests and put extra pressure on the instructors in the practice-based elements of their modules:

> We had an assessment yesterday. At the tutorial, before the assessment, people were panic-asking how to do these big chapters of maths because they do have no idea. And in his slides, and stuff, he'll put examples, but we'll never do them. And then there's no answers to the examples. So, it's not very practical. I, personally, haven't learned anything in that class . . . I'd rather just have 2 hours of the tutorial. (I4)

The only classes in which the students enjoyed instructor-centred lectures with little interaction between the instructor and students as well as little individual and group activity, were biology classes. Students described them as "straightforward" even though they "kind of just sit there and then leave [laughs]" (I6). It might be that in subjects that are traditionally perceived as less difficult and for which the self-efficacy of female students is higher, students depend on the use of active learning methodology and instructional scaffolding less. Students described classes with a chemistry or biology element as easier while physics and mathematics were quoted as subjects students were struggling with. This was reflected in the students' responses to the self-efficacy questionnaires as well. Students described being less interested and motivated in classes that they perceived as difficult:

> We have histology and anatomy and physiology. Those I find easier because I think I have that kind of mindset: if I can see it, I can understand it better. Whereas the ones I'm not really interested in as much is the physics part. And that's, you know, very— I'm struggling with that even more compared to the ones I find easy . . . The stuff that I'm not— yeah, it's harder for me to be more motivated, to be better at physics, or whatever, specifically. (I5)

Students that perceive their courses as difficult have been found to have increased course anxiety and perform worse (England et al., 2019), which is known to affect student self-efficacy beliefs negatively. In addition, self-efficacy has historically been linked with student interest (Lent et al., 1991). Therefore, subjects that women and gender minority students identify as difficult or describe lacking interest in, in this case, mathematics and physics, might especially benefit from pedagogical self-efficacy interventions.

Just like in lectures, students' sentiment towards their tutorial classes depended heavily on the use of student-centred approaches. According to the students, tutorial classes are only as purposeful as they allow them to put what they have learned in lectures into practice. Tutorials offer an opportunity for the students to test their knowledge and prepare for assessment:

> I think it's just— you put to work what you've learned in class . . . You're not penalised on that . . . and you can test yourself and see what you know, what you don't know, and what you've got to focus on. (I11)

The tutorials which resembled lectures were unpopular with students and were usually not well attended:

> We have tutorials for— in physics, maths, and chemistry. In chemistry and physics, you get more people showing up, so most of the time I would go to one of those. Biology and physics, they're good, but I'm not a big fan just because the lecturers are just going through the answers . . . so it's not really interactive. (I8)

Students much preferred the tutorials in which the instructors made time for students to attempt to answer the worksheet questions. While some instructors prefer to have the students complete the worksheet by themselves prior to the tutorial and then go through the solutions together and others simply present the students with the solutions to the worksheet questions, often for the sake of saving time, students rely on the allocated class-time to engage with the worksheet material. Students also did not find it beneficial to go to the tutorials in which they could not address their questions or receive satisfactory answers to their questions. Students felt that the ability to interact with the instructor effectively was essential to how useful they found the tutorials to be:

> Tutorials weren't great at the start, I won't lie. One of them was in, you know, the big lecture hall (lecture hall number)? It was just our class with like 30 people in that massive lecture hall. He couldn't help us because everyone was just talking. (I4)

Students found the tutorials in which the instructor made time for them to attempt solving the problems themselves immensely helpful and felt that they were able to "actually learn something" (I4), especially when such tutorials supplemented lectures that relied on didactic instruction. The instructor's ability to offer students individual attention was often instrumental in supporting student learning in a tutorial setting.

Laboratories are heavily practice-based and students unanimously found them engaging and useful. This was often because they gave them "an insight of what techniques and skills and just general things you'll have to use in the future going into the actual profession." (I10) Students were especially fond of the laboratories that equipped them with professional skills:

> I see myself always looking forward to any of the labs. We have a physics lab, we have a geo optics lab, and a vision science lab. Because it's very hands-on, we're actually doing stuff. We, you know, really see the results of what we're doing. And you have the vision science . . . It's one of our— one of my favourite ones because we actually get to test each other's eyes and we did the whole thing as if we're already practising opticians. And it's pretty cool. (I11)

Students referred to laboratories as "very practical" and found they contributed to their learning more than didactic classes: "I learn a lot by doing so I find it really helpful." (I12) This replicates the findings of previous studies regarding the use of active learning methodologies in STEM contexts, which have correlated student-centred learning with better knowledge of course material (Ballen et al., 2017), improved performance on assessments, and reduced course failure (Freeman et al., 2014).

Stress & Anxiety

Students in their first year of university education are bound to experience increased levels of anxiety due to a lack of familiarity with a university setting. Students in the focus group described experiencing increased anxiety when dealing with unfamiliar topics:

> I always get really nervous before any lecture, if we're doing a new topic, I'm always really worried about— when we go on to something that throws me in at the deep end, that I won't know what's happening. If anybody's going to ask questions, that I'll just get lost, and that happens, like, every single lecture. I'm always like, "This will be the one, I feel it", like, "Oh no..." [laughs] (I10)

Other students explained how not being able to follow the topic or feeling like they are falling behind in one subject undermined their self-confidence and affected their performance in other subjects as well:

> I think it's really like, **if don't understand it, then that makes me anxious**. They're kind of, when they're teaching, they go, "Oh, this is important. Learn it. Know it." And I'm like, "I don't understand what you're talking about." I just feel like I'm going to start falling . . . I start off really well and I'm having a really good week. And then the next week, **once I hit a little bump in the road, then the confidence starts going down. And then it's kind of just— it's like a domino effect. So, if I got my mind on one thing, the rest of the things— I'd focus on this solely and the rest of the work has to be on pause.** You're solely focused on this one thing. And that starts affecting all the other ones . . . and if I'm already struggling with that initially from not learning the material, then it just gets bigger and bigger. (I5)

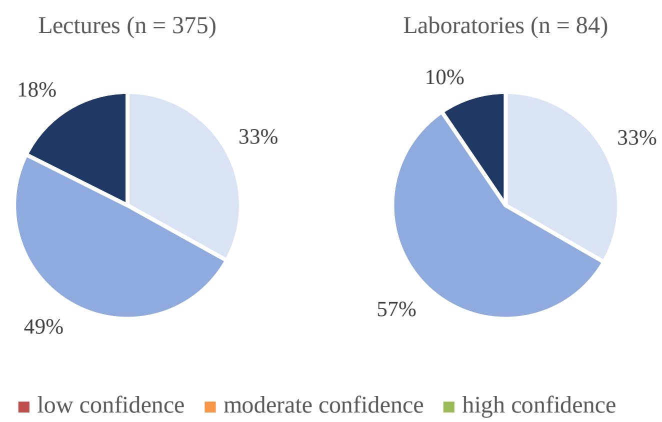
While students brought up laboratories as classes that contributed to their self-efficacy the most, the percentage high-confidence students in laboratories was lower than in lectures (Figure 17). Active learning methodology has often been linked with heightened anxiety. Therefore, women and gender minority students might be especially susceptible to anxiety in laboratory classes, since they have been consistently found to exhibit higher anxiety levels in STEM than men (Ballen, Salehi, et al., 2017; Malespina & Singh, 2022; Mallow, 1994). Students in the focus group pointed out that in a laboratory setting, insufficient instruction at the beginning of the class often led to feelings of uncertainty and confusion:

> Sometimes in the physics lab, they expect you to know what you're doing, even if you've never done physics before. They don't go through, at the beginning, what you need to do, they don't explain it to you properly. And they just expect you to know what you're doing. (I7)

According to the students, only receiving "a brief instruction of what you're meant to do" (I8) is not enough to guide them through complex laboratory tasks. While, in a laboratory setting, individual assistance can always be provided, students may feel insecure about having to ask for help. In addition, laboratory reports often need to be completed after class, when immediate support is no longer available: "I find that afterwards, we're kind of left with four pages, or whatever, to fill in, but they haven't really gone through it. So, we're kind of left trying to figure that out." (I9) Other students observed that laboratory classes were usually higher-stake and they felt more pressured to perform well:

> I think, what makes me the most anxious, even though I do love the vision science labs, I just find there's loads of responsibility already. Because, you know, we're going to be doing this with the public when we're working. You know, you have to do it right to, kind of, help them. So, I kind of just— it makes me nervous whenever I get it wrong, or I don't know how to do it properly. (I12)

Figure 16. Comparison of Student Self-Efficacy in Lectures and Laboratories (n = 459)



Active learning practices caused anxiety in a lecture setting as well. Several focus group participants brought up cold calling as a practice that heightened their anxiety. Being called upon while dealing with an unfamiliar topic or not knowing the answer has been identified as stressful by several students:

> Our lecturer actually calls us out. Sometimes there is an anticipation of being called out, especially if you're listening and you know the right answer. But other times, when you're not paying attention, it is kind of — the anxiety does go up slightly. (I3)

> I think in maybe two of our modules they call on people randomly if there's no answer. Sometimes our lecturers literally just pull out a name, you know, just from the top of their head. So sometimes you're like, "Oh my god, I hope they don't know my name," or "Thank god, they don't know my name, because I don't want to answer this question, I don't know." (I12)

> Well, he asked us, and it was a new lecture, it was our first lecture with him . . . So, when he asked us, it was like a debate about religion and sciences. And I had no idea what to say. I didn't have any opinions on it myself. So, it's kind of hard when someone's waiting for you to answer. You just don't know what to say, everyone's watching you. (I4)

Utilising cold calling as a teaching practice might be detrimental in introductory classes with first-year students, in particular, since their subject knowledge is limited, and they rely on positive performance achievements to help inform their self-efficacy beliefs in a new domain.

For other students, the use of personal response systems in the classroom contributed to increased levels of stress and anxiety. The stress was mostly related to the questions being timed and graded, as well as being different from the questions the students had practiced with:

> I think it's really whenever we have an MCQ (multiple-choice question) coming up. It's like, we do have little practice ones for some of our lectures, but then what comes up on the MCQ is — the practice one is very different to what comes up on, what we're being tested on. Sometimes, it's similar. Sometimes, it's very different. So just — and the fact that the MCQs have a weigh-in in our continuous assessment . . . it's extra pressure, it's like I have to do it right. And then you just see the timer ticking, it's just like, "Hurry up, hurry up!" (I11)

While I11 reported that having practice clicker questions helped them prepare for assessment situations, they found that they were less beneficial if they were limited in number or did not explore all the possible topic areas:

> For our practice ones, it's unlimited. You can try as many times as you want. But the thing is, the practice ones, it's just the same questions over and over again, which isn't very helpful because, if you got three wrong the first time, you'll know what three you got wrong, and then you'll fix them and you'll get a 100% on your practice one. But then on the actual one, it's not really the same questions or it's not really similar questions even, so— then you don't know. You're just kind of thrown into it, it's like whatever comes up, comes up. (I11)

Interestingly, the students in the focus group did not mention other types of timed and graded continual assessments as contributing to increased anxiety. It may be that the immediacy of response required when answering multiple-choice questions was the biggest contributor to student anxiety since the time the students are allowed to deliberate on their answers is very limited. Other timed and graded continual assessments, such as quizzes, may be more generous with the allocated time and allow for more deliberation, which could have a positive effect on student comfort.

Knowledge Application and Performance Feedback

When discussing what contributes to their feelings of self-efficacy, almost all students brought up achievement situations and the ability to apply their knowledge in practice. Students mentioned that understanding the topic and feeling like they will be able to apply their knowledge in an assessment increased their confidence. Other students relied on practice-based classes to gain information about their capabilities. Students mentioned that they felt most confident when they were able to put what they have learned in a lecture setting into practice in a laboratory and got satisfactory results. One student explained how utilising theoretical knowledge in a lab setting made them feel confident by increasing their understanding of the subject:

> I'm really confident in a subject if I'm able to apply but also understand— if there's a topic that we've covered in class and if I'm able to finally understand it in a lab, or something, I feel satisfied and like, "Ok, I get it, I understand why this happened and why we're doing this." (I10)

Other students mentioned that being able to use the knowledge they gained in their classes to engage with others contributed most to their self-efficacy. Some students were most confident when able to exchange knowledge about their subject with their peers:

> For me, whenever I sit down with other people, whatever, and we all, kind of, we all have the same problem. And then we come to, we find out, we figure it out together. Or when someone else is teaching us how to do it. Sometimes the lecturer just doesn't work. And then... when you're the one who knows the thing, and you're helping others, you're reinforcing it for yourself. Like, I know it, but I also helped my friends. So, I like getting the help and helping others, that's a little confidence boost. (I11)

Other students explained how using their knowledge when engaging with others outside of the university environment and in more practical situations boosted their confidence:

> For me what kind of builds my confidence… I like going home, and telling my parents about, when I learned something, or, if they're asking a question about, some questions about their eyes, because, you know, they both have bad vision. And so, you know, we're all kind of really interested in what's going on with ourselves. So, whenever I'm able to explain, "This is actually what the optometrist is telling about your eye", or "This is what's happening with your eyes", or something— that, kind of, makes me satisfied with the content that I've learned. And that gives me confidence. (I12)

While students did not bring up group work when talking about classroom practices that contributed to their confidence the most, the positive sentiment they expressed towards informal situations in which they can share their newly gained knowledge with others advocates for more instances of collaborative and peer-based learning practices in STEM classrooms.

Other students relied on performance feedback, such as marks and instructor feedback, to form their self-efficacy beliefs. Some mentioned general performance indices, such as "doing well academically" (13), as contributing to how capable they perceived themselves to be. Other students referred to more specific achievement opportunities and mentioned performing well on tests as well as doing well on the continuous assessments as helpful in boosting their confidence. While for some of the students performing well in any assessment situation meant increased confidence, others identified smaller-scale assessments as most impactful in influencing their self-efficacy positively and helping them sustain confidence and motivation over time:

> I like bite-size quizzes, not something that's, like, a huge quiz, where you spend hours and hours just going through papers, and going through your notes, but something bite-sized that gives you that small little satisfaction of like, "Yes, I understood this part of the topic", like, "What's the next one?". Because it keeps you engaged, I think. And, at least for me, because I struggle extremely, when it comes to long hours of lectures and studying, so a one-hour lecture, then half an hour in a quiz gives me that small satisfaction that I need. I'm sort of praising myself with the work that I've been

> doing by seeing the number that I get on the quiz. So that's what motivates me and gives me confidence. (I2)

Another student pointed out how they think smaller-scale continuous assessment tasks are a better representation of one's capability in regard to specific topic areas:

> I think I'm the same, I kind of like the smaller pieces of continuous assessment. Because, obviously, in a big exam, you've got a lot more to remember. So, you're not going to remember, and your grade might dip a bit, but with the continuous assessments, you get a good grade, it's like, "Oh, actually, I did understand this, I'm doing well." (I3)

The participants in the focus group also mentioned the importance of instructor feedback for their confidence. According to them, instructor feedback can work as verbal encouragement and "a bit of praise can go a long way" (I13) in increasing their self-efficacy. The students also relied on the feedback from their instructors to be able to adjust and improve their performance, especially in practice-based classes:

> Especially when they tell you what to repeat and improve on. I really feel like in those type of lectures, I don't do— I didn't do as great in my first class as I did in my second one. Our first lab was, you know, "Go off and do it and see what you can do." And then when we got the feedback, my second lab was a lot better than my first one. So, I applied the feedback, and then it was, you know, rewarding, and it was good to see that the bad feedback helped me up my grade. (I11)

One student, however, shared that they were struggling with self-confidence and that not even positive performance feedback could help them feel more confident:

> I'm sorry. [Pause] I don't have anything. I think when you asked that question, I was like, immediately in my head, I was like, "Oh, major confidence…" I don't think, to be fair, I've ever had major confidence. Even if I do get good results. I'm like, "Oh, I could do better." It's a decent grade. I'm happy with it. I'll take it. I know I can do better, but — even with a little bit — it's like a tiny thing for me, it's not a huge thing. I don't know. And, I guess, I don't like to say that out loud because that makes — I don't want to offend anyone if people get lesser scores than me . . . So, I keep it to myself. So, I feel like that might have affected the way I see myself when I get a good grade. It's just like, "Oh, that's— that's okay." (I5)

While performance accomplishments are known to be one of the strongest influencers of self-efficacy beliefs, there are many other factors affecting student self-efficacy. Student demographics, educational background, and ability and confidence beliefs formed before entering university education all have an impact on how students interpret their performances, especially at the beginning of their studies, when students have been exposed to limited achievement opportunities in a higher education setting. In addition, the self-beliefs of some students might be more pervasive and resistant to change than others. Certain demographics (e.g. women) are known to possess lower self-efficacy in STEM even when achieving high results (Marshman et al., 2018) and to have a more severe reaction to failure, often blaming the intrinsic lack of ability (Nauta et al., 1999). Interestingly, I5 pointed out that performing below their usual standard did not affect their self-confidence in a significant way either:

> I mean, I have — obviously, everyone has their own expectations for themselves, and they know what they can achieve. But I feel like no matter what I get, even if I fail . . . I am like, "Oh, that's what I get. Sure. I'll try again next time."

It might be that in the case of this student their strong, negative pre-existent self-efficacy beliefs might have undermined the effect of new mastery experiences and left this student unaffected by occasional low performances as well as unmotivated by academic success (Bandura, 1997; Zander et al., 2020).

Assessment Practices

Previous studies have suggested that smaller-scale tasks are most effective in helping first-year STEM students build up their confidence over time (Dalgety & Coll, 2006; Malespina & Singh, 2022). Exams, on the other hand, require immense preparation and thus, in exam situations students are tested on their ability to organise their learning, their study and exam skills, as well as their knowledge in a particular subject. Students belonging to minority groups may lack these skills (Roscoe, 2015). In addition, students underrepresented in STEM have been found to experience higher stress levels in regard to exam situations (Ballen, Salehi, et al., 2017; Malespina & Singh, 2022).

In this study, on average, all students felt less confident about exams than continuous assessment tasks. This was true for all age, ethnic, and generational groups. When it came to gender, only gender minority students felt equally confident about both continuous assessment tasks and exams, while both men and women felt more confident about their performance in continual assessment tasks (Table 5). In regard to exams, women represented the largest part of low-confidence and the smallest part of high-confidence students. This could mean that female students with low self-confidence perceived exam situations as more threatening than male and gender minority students. Ballen and associates (2017) found that women had higher anxiety and performed worse on examinations then men, but outperformed men on non-exam modes of assessment in introductory Biology. Therefore, courses utilising a variety of assessment methods might help the self-efficacy beliefs of women and gender minority students in undergraduate STEM courses in particular.

Table 5. Student Self-Efficacy: Gender x Assessment Type

Self-Efficacy: Marked Assignments vs Exams

		Assignments		Exams	
		%	n	%	n
female	low confidence	35.7	100	45.0	126
	moderate confidence	49.3	138	45.0	126
	high confidence	15.0	42	10.0	28
male	low confidence	27.6	53	38.5	74
	moderate confidence	48.4	93	42.7	82
	high confidence	24.0	46	18.8	36
gender minority	low confidence	36.4	4	36.4	4
	moderate confidence	36.4	4	36.4	4

high confidence	27.3	3	27.3	3

5. SUMMARY AND CONCLUSION

5.1 RQ1: SELF-EFFICACY x STUDENT PROFILE

This study sought to identify the existing self-efficacy trends among students in undergraduate STEM programmes. While students participating in the study were fairly confident overall (M = 10.94, SD = 2.702), student confidence was largely dependent on their profile.

5.1.1 Student Demographics x Self-Efficacy

In regard to student gender, male students were the most confident among the students in the sample, gender minority students were second most confident, and female students were the least confident. The self-efficacy beliefs of gender minority students were the most inconsistent (SD = 2.830) and the students in this group had the largest share of low-confidence students among all gender groups. Female students had the lowest share of high-confidence students, with only 12% of female students falling into the high-confidence category. The relationship between student gender and self-efficacy was statistically significant (x^2 (2, n=483) = 12.044, p = 0.002, φ = 0.158). No significant relationships in bivariate analyses were observed between self-efficacy and student age, race/ethnicity, and socioeconomic background (generational status). Nevertheless, young mature students (age 21-25) were considerably more confident than their traditional age (<21) and mature (>25) peers, and black students had the lowest self-efficacy scores among all race/ethnicity groups. Interestingly, students categorised as other race/ethnicity and mixed background displayed the highest self-efficacy scores within the race/ethnicity category. No notable differences were identified between first-generation and continuing-generation students.

5.1.2 Study Field x Self-Efficacy

A statistically significant relationship was observed between student self-efficacy and study field (x^2 (8, n = 454) = 16.892, p = 0.031, φ = 0.193). Students in engineering and computing university programmes scored highest on the self-efficacy scale, while students in the interdisciplinary study programmes had the lowest self-efficacy. The largest gender discrepancies according to study field were observable in biology and health and interdisciplinary fields. Seeing how the majority of the interdisciplinary programmes belonged to the Physics School and the majority of the students (79.1%) in the interdisciplinary programmes were female, it is possible that gender stereotypes associated with the field of physics help explain the low self-efficacy results among students in interdisciplinary programmes. The considerably larger proportion of high-confidence male students (32%) than female and gender minority students in biology and health study programmes could not be explained.

5.1.3 Previous Performance x Self-Efficacy

A statistically significant positive correlation was also found between previous performance and academic self-efficacy (τb = 0.096, p = 0.031). Students who reported achieving higher scores in their Leaving Certificates were also more confident about their capabilities to perform well in their university classes, while those who reported low scores exhibited significantly lower self-efficacy. The low-performing student group (<326 LC points) had the largest share (50%) of low-confidence students, while the very-high-performing group (>525 LC points) had the lowest share (24%) of low-confidence students and the highest share (26%) of high-confidence students.

5.2 RQ2: SELF-EFFICACY X PEDAGOGICAL PRACTICE

5.2.1 Class Setting x Self-Efficacy

In regard to classroom practice, two factors concerning class setting had a significant influence on student self-efficacy. Students had higher self-efficacy for large-enrolment classes: class size had a weak positive correlation with student self-efficacy ($\tau b = 0.083$, $p = 0.045$). Instruction week, however, had a medium-strength negative correlation with student self-efficacy with students becoming increasingly less confident as the semester progressed ($\tau b = -0.156$, $p<0.001$).

5.2.2 Pedagogical Practice x Self-Efficacy: Class Observations

Lower proportions of low-confidence students were observed in laboratories and tutorials that prioritised student-centred approaches, where students actively engaged in both individual and group tasks for the majority of the class. Conversely, laboratories and tutorials with the highest percentage of low-confidence students were primarily based on didactic instruction.

Lecture observations, however, produced less decisive results, with a highly interactive physics class having the lowest average self-efficacy score and the second highest share of low-confidence students among all observed classes and a low-participation biology lecture having one of the highest self-efficacy scores and one of the lowest shares of low-confidence students. It might be that the perceived subject difficulty and subject-related expectations concerning innate ability (Leslie et al., 2015) influenced the results of the self-efficacy survey in those classes. Nevertheless, when comparing lectures with the highest and lowest proportions of low-confidence students, both of which happened to be in the same computing and digital skills subject, it became apparent that active learning methods and student-instructor interaction played a crucial role, with drastic differences in the share of low-confidence students observed between a class where students engaged in some student-centred learning activities and a purely didactic class.

The classification and regression tree analysis was employed to help gain a better insight into which pedagogical practice can best predict student confidence in first-semester STEM lectures. Three codes were found to predict student confidence in a lecture setting: student codes ‘waiting’ and ‘individual thinking/problem solving,’ and instructor code ‘real-time writing.’ Reduced waiting and more individual thinking/problem solving opportunities correlated with higher confidence. Students were predicted to be the least confident in classes in which ineffective use of class time (prevalence of code ‘waiting’ >2.5%) collated with instructor-centred teaching methods (prevalence of code ‘real-time writing’ >60.8%).

5.2.3 Pedagogical Practice x Self-Efficacy: Focus Group

The findings of the focus group discussion provided some valuable insights about which teaching and learning practices are the most valuable to women and gender minority students. The focus group participants highlighted student-instructor relationships as especially important to positive learning experiences and talked about such instructor qualities as friendliness, attentiveness, and understanding as contributing to their learning positively. Students identified that they felt most supported in classes which utilised sufficient instructional scaffolding and provided them with individual attention and feedback. However, the extent to which the students relied on active learning methodology depended highly on the subject matter. Students described their mathematics and physics classes that involved active learning methodology as helpful and engaging, while mathematics and physics lectures which relied on didactic instruction were perceived as difficult and ineffective. However, students seemed to enjoy didactic biology lectures. It was especially important for students that their tutorial classes, which are often based on practice sheets, involved individual thinking opportunities. Students commonly quoted laboratory classes as contributing to their sense of self-efficacy the most because they provided them with opportunities to apply their knowledge in practice and equipped them with practical skills.

Stress and anxiety were important factors in early STEM experiences of female and gender minority students as well. Some students mentioned that dealing with unfamiliar topics was enough to raise their anxiety, while others highlighted struggling with the course material as one of the biggest stressors in the first semester of their study programmes. In regard to specific pedagogical approaches, students found laboratory work, especially when paired with minimal instruction, cold calling, and timed and graded multiple-choice questions highly stressful.

Other types of continuous assessment have been almost unanimously highlighted as contributing to student self-efficacy positively. Students found that continuous assessments were easier to prepare for and provided more immediate performance feedback. In addition, students mentioned that their confidence in first-year classes could be sustained through frequent participation in continual assessments. While students in the focus group did not discuss exams in detail, the self-efficacy questionnaire results indicate lower student self-efficacy for exam situations than for continual assessments. Based on the results of the focus group interview and the self-efficacy questionnaire it appears that non-exam modes of assessment are preferred by all students.

This study reveals that student self-efficacy towards STEM classes depends on factors relating to student background, class setting, and educational practice. Early university experiences are important for student retention in STEM fields (Maltese & Tai, 2011) and evidence from this investigation suggests that pedagogical practice known to positively affect self-efficacy, such as ample active learning and knowledge application opportunities, personalised feedback, and instructor support and encouragement, has a positive effect on the learning experiences, interest, and engagement of the female and gender minority students in undergraduate STEM programmes.

6. IMPLICATIONS FOR LEARNING AND INSTRUCTION

For students underrepresented in STEM, negative university experiences often result in a loss of confidence (Seymour & Hunter, 2019), which can have severe implications for their academic and professional development. Based on the findings of this study, several pedagogical considerations should be taken into account when trying to enhance student confidence and support the retention of undergraduate students in STEM by encouraging positive university experiences among undergraduate students.

6.1 STUDENT-STAFF RELATIONSHIPS

This study revealed that student-instructor relationships and interactions are at the core of positive learning experiences among students in introductory STEM classes. Positive relationships and effective communication between students and staff were found to contribute to establishing a pleasant classroom climate and help keep the students engaged and motivated. The participants in this study identified that they formed the best relationships with their instructors in classes where the instructors were approachable, available, and attentive to the needs of the students. In addition, ample opportunities for instructor-student interactions, both in whole-class and one-on-one scenarios, were essential to establishing strong relationships between students and staff. Based on the findings of this study, instructors concerned with enhancing student learning experiences should proactively engage with the students in STEM classrooms and make time for student questions and concerns. Furthermore, a conversational tone and accessible language used in class can help improve instructor-student relationships and encourage more active participation among students in undergraduate STEM courses.

6.2 PEDAGOGICAL PRACTICES

In order to promote positive learning experiences among undergraduate students, instructors in STEM courses should try and avoid teaching practices commonly associated with increased student anxiety. Such instructional practices as cold calling or timed and graded personal response systems are commonly perceived as stressful, especially in undergraduate contexts. Instructors that insist on utilising these practices might want to consider strategies that can help mitigate some of the stress associated with them. Only cold calling students on questions regarding familiar topics, only utilising cold calling in smaller classes, allowing students to confer in pairs or groups, and calling upon group representatives rather than individual students are some helpful practices in mitigating student anxiety (Lübeck et al., 2022). While personal response systems have been found to enrich the learning experiences of students (Sun, 2014), instructors may want to avoid using them for timed and graded assessments. While a certain amount of stress in assessment situations is expected, students did not report the same anxiety towards other methods of timed and graded continual assessment, such as quizzes. In non-assessment situations, personal response systems are also best utilised with familiar topics and when the students can anticipate what they will be questioned about, e.g., at the end of the class when reflecting on the learnt content, or at the beginning of the class when revisiting material learnt in the previous class. Anxiety associated with clicker questions can be further reduced if the instructors make time for discussion regarding the correct answer and common mistakes after the students have submitted their answers (Lübeck et al., 2022).

Furthermore, instructors concerned with facilitating positive learning experiences among their students should be aware of instructional practices identified as relating to student disengagement. Instructor-centred teaching, content overload, suboptimal use of class time, incoherent or inconsistent instruction, and boring delivery have been found to cause student disinterest, lack of motivation, and difficulties in engaging with the course content in previous research (Seymour & Hunter, 2019) as well as in this study. On the other hand, student-centred pedagogies were found to positively correlate with student learning experiences both in a lecture setting and in practice-based classes. It is particularly important for instructors to embrace active learning pedagogies in classes commonly perceived as challenging, such as mathematics and physics. In addition, students in this study perceived the tutorial classes in which they were able to actively engage with the material as having higher value. Some concerning attendance issues identified during class observations and reported by the students in the focus group related to how interactive the tutorial classes were, with students likely to disengage and stop attending tutorial classes based on didactic instruction. While simply presenting students with solutions to worksheet problems they are required to address at home might seem like an effective use of class time, the evidence presented in this study suggests that instructors concerned with the engagement and confidence of students in tutorial classes should centre their classes around mentored individual thinking and problem-solving activities. What is more, it is crucial that active learning activities in science laboratories be preceded by sufficient instruction, especially in laboratories in which the students have differential levels of previous experience. Proactive provision of individual attention and feedback to students in science laboratories can help instructors strengthen the positive effects of active learning on student confidence.

6.3 ASSESSMENT

Instructors in undergraduate STEM courses should consider designing their courses to include frequent assessments and offer diverse assessment types. In agreement with previous studies which revealed that exam modes of assessment disproportionally disadvantage female STEM students (Ballen et al., 2017; Malespina & Singh, 2022), this study found that while all students were less confident about their capabilities to perform well on exams than on continuous assessments on average, women felt less efficacious towards exams than gender minority and male students. Therefore, instructors who incorporate non-exam modes of assessment into their classes can help intentionally support female students in their classrooms and contribute to more positive experiences in assessment situations among all students.

Instructors concerned with facilitating positive assessment experiences should also try and prevent failure since it might damage the vulnerable self-perceptions of first-year students. Therefore, instructors in undergraduate STEM classes should utilise multiple low-stakes assessments. Previous research has suggested that smaller-scale assessments, such as solving worksheets or quizzes, may help students in introductory courses become progressively more confident and support the development of their study and exam skills (Dalgety & Coll, 2006; Malespina & Singh, 2022). This study also found that smaller-scale quizzes were particularly important to the development of self-efficacy beliefs of female and gender minority students. Therefore, instructors who provide their students with smaller-scale, low-stake assessment opportunities can help students build a robust sense of subject-related confidence over time, especially if they supplement those opportunities with personalised performance feedback.

7. LIMITATIONS AND FUTURE RESEARCH

Gender minority students (n = 11) in this study represented 2.3% of all participants. The descriptive analysis of the results of the self-efficacy questionnaire among gender minority students provided some interesting insights. Even though gender minority students were rather confident on average, they had the highest proportion of low-confidence students (36%, n = 4) among all gender groups. While the number of gender minority students in this study was too small to draw any generalisable conclusions, previous research reveals that undergraduate STEM education may present unique challenges for gender minority students (Campbell-Montalvo et al., 2022), highlighting the need for targeted support. While a wide range of obstacles gender minority students face in higher education has been acknowledged in Ireland (Chevallier et al., 2019) and elsewhere (Lawrence & McKendry, 2019), research concerning pedagogical practice and student self-efficacy often involves binary genders only. Seeing how the number of people identifying as gender minority is increasing (Barbee & Schrock, 2019; Meerwijk & Sevelius, 2017), further studies regarding pedagogical practice in higher education may want to concentrate on gender minority student self-beliefs specifically or explore the intersections between gender and LGBT identity.

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APPENDIX

APPENDIX 1: SELF-EFFICACY SURVEY

Self-efficacy beliefs among undergraduate STEM students at TU Dublin

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Consent

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1. Do you consent to taking part in this study?
   ☐Yes
   ☐No

Personal Details

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2. Programme name (e.g. ‘TU755’ or ‘Science General Entry’)

3. Age
   ☐<21
   ☐21-25
   ☐>25

4. Race/Ethnicity
   ☐White
   ☐Black
   ☐Asian
   ☐Latin American
   ☐Middle Eastern and North African
   ☐Romani and Irish Traveller
   ☐Other/Mixed background

5. Gender
   ☐Female
   ☐Male
   ☐Gender minority (non-binary, transgender, etc.)

6. First-generation university student (parent(s) did not complete a university degree)
   ☐Yes
   ☐No

7. When did you take your Leaving Certificate examinations (year)?

8. Irish Leaving Certificate points (if applicable)

9. How confident are you that you can do the following tasks in your [CLASS NAME] class?

	1 not at all confident	2 somewhat confident	3 mostly confident	4 completely confident
understand the most difficult concepts taught in your [CLASS NAME] class	☐	☐	☐	☐
master the skills taught in your [CLASS NAME] class	☐	☐	☐	☐
do well on the assignments (continuous assessment, as well as ungraded homework and in-class activities) in your [CLASS NAME] class	☐	☐	☐	☐
do well on exams in your [CLASS NAME] class	☐	☐	☐	☐

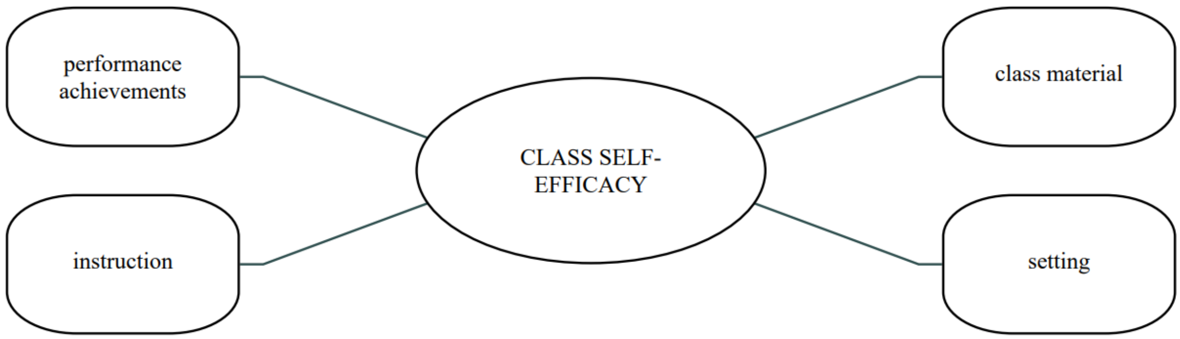
APPENDIX 2: EXAMPLE CLASS OBSERVATION SHEET

	Students													Instructor												Comments
min	L	Ind	CG	WG	OG	AnQ	SQ	WC	Prd	SP	TQ	W	O	Lec	RtW	FUp	PQ	CQ	AnQ	MG	1o1	D/V	Adm	W	O	
1-2																										
2-4																										
5-6																										
7-8																										
9-10													✓										✓			End of survey Class begins Instructor takes attendance with a QR code
11-12	✓													✓												Lecture begins Students have handouts with lecture notes
13-14	✓													✓												
15-16	✓													✓												
17-18	✓													✓												IIstructor points out which concepts are important/will come up in the lab
19-20	✓													✓												
21-22	✓													✓												Slide titles phrased as questions (e.g. what is meiosis?) represent questions that will be in the assessment
23-24	✓													✓												
25-26	✓													✓												Students take notes more actively in regard to test questions
27-28	✓													✓												
29-30	✓													✓												Students listen to the instructor carefully, there's almost no talking/whispering
31-32	✓													✓												
33-34	✓													✓												The handout is black- and-white Instructor advises students to colour in the illustrations

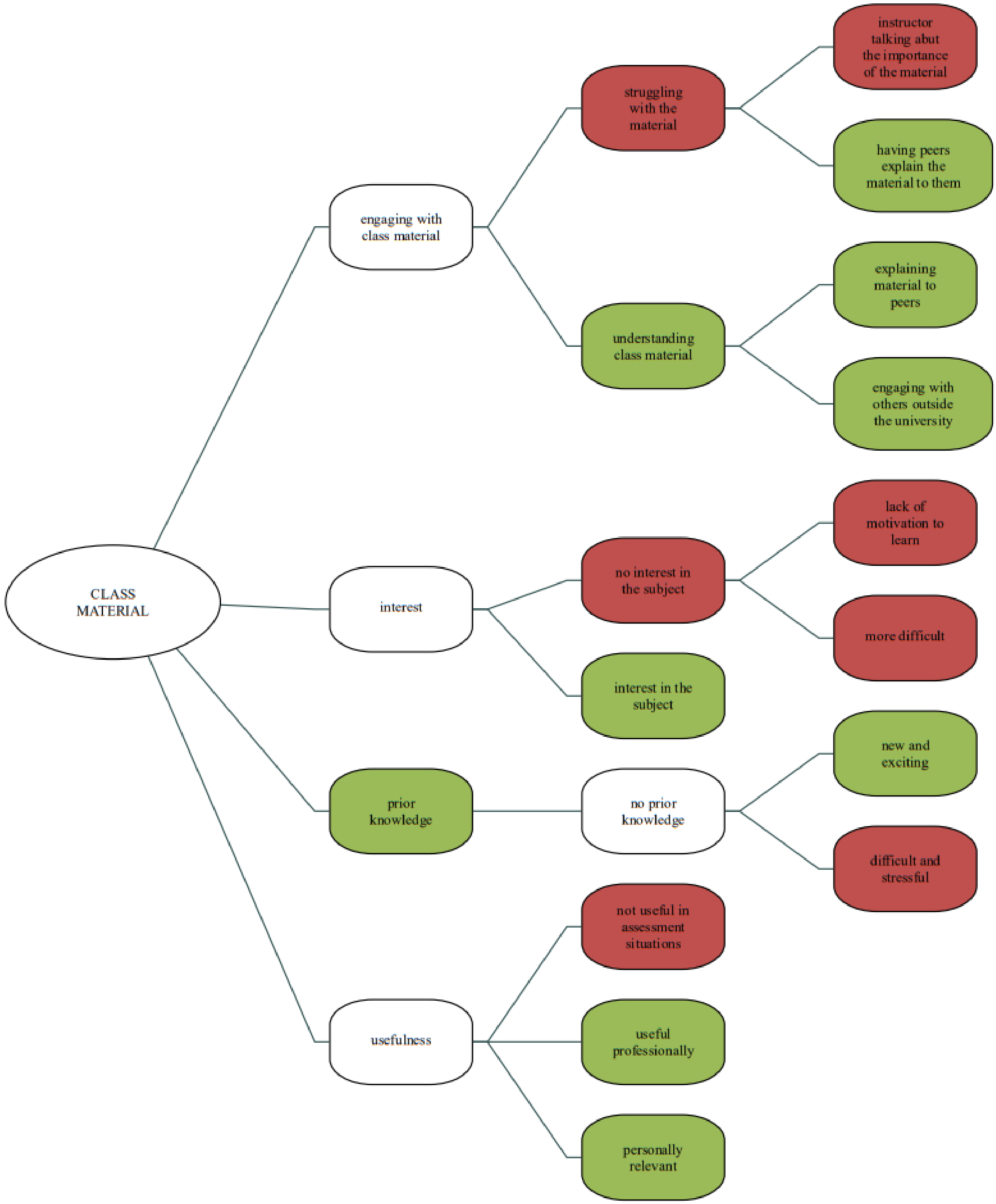
																										Students are continuously advised on what to highlight/note down since it will come up on the test A group of students arrive late
35-36	✓													✓												Students in the back row begin chatting quietly
37-38	✓													✓												
39-40				✓													✓			✓						Think-pair-share question: Why is genetic variation important? Instructor goes around the class making certain that students have formed groups Some students are confused about what they are supposed to be discussing, the instructor clarifies that for them Students are asked to put down the results of their discussion on a piece of paper containing their names
41-42				✓																				✓		Students are engaged in discussion
43-44				✓																✓	✓				✓	Instructor is collecting responses
45-46	✓													✓		✓										Instructor reads some of the responses and mentions which are most accurate/would be assessed highly in a test situation
47-48	✓					✓								✓		✓	✓									Students in the back row are getting a bit noisy
49-50	✓													✓		✓										End of class Students are encouraged to have a look at/ answer their tutorial questions (online)

APPENDIX 3: FOCUS GROUP INTERVIEW. MAP OF THEMES

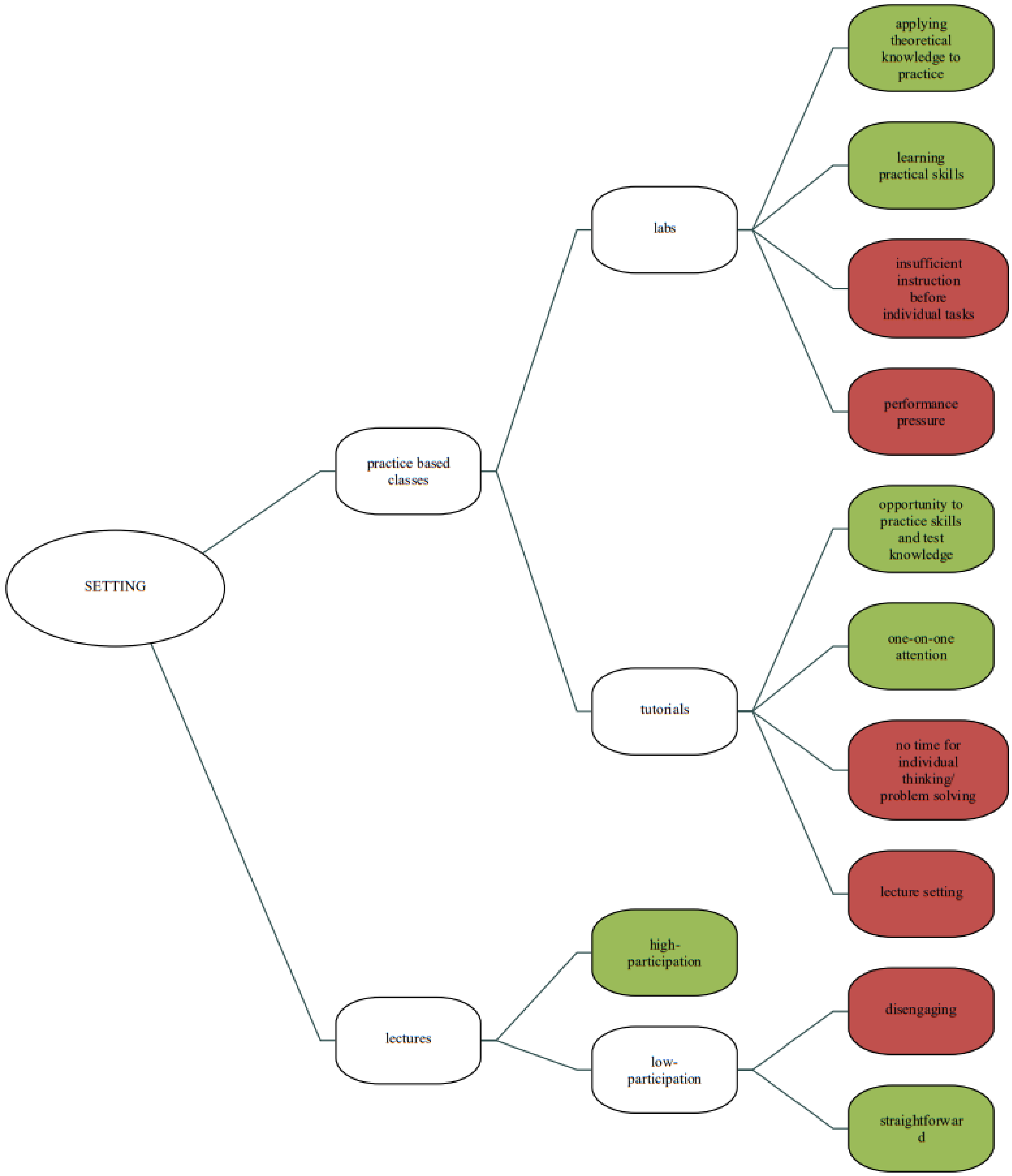
Class Self-Efficacy



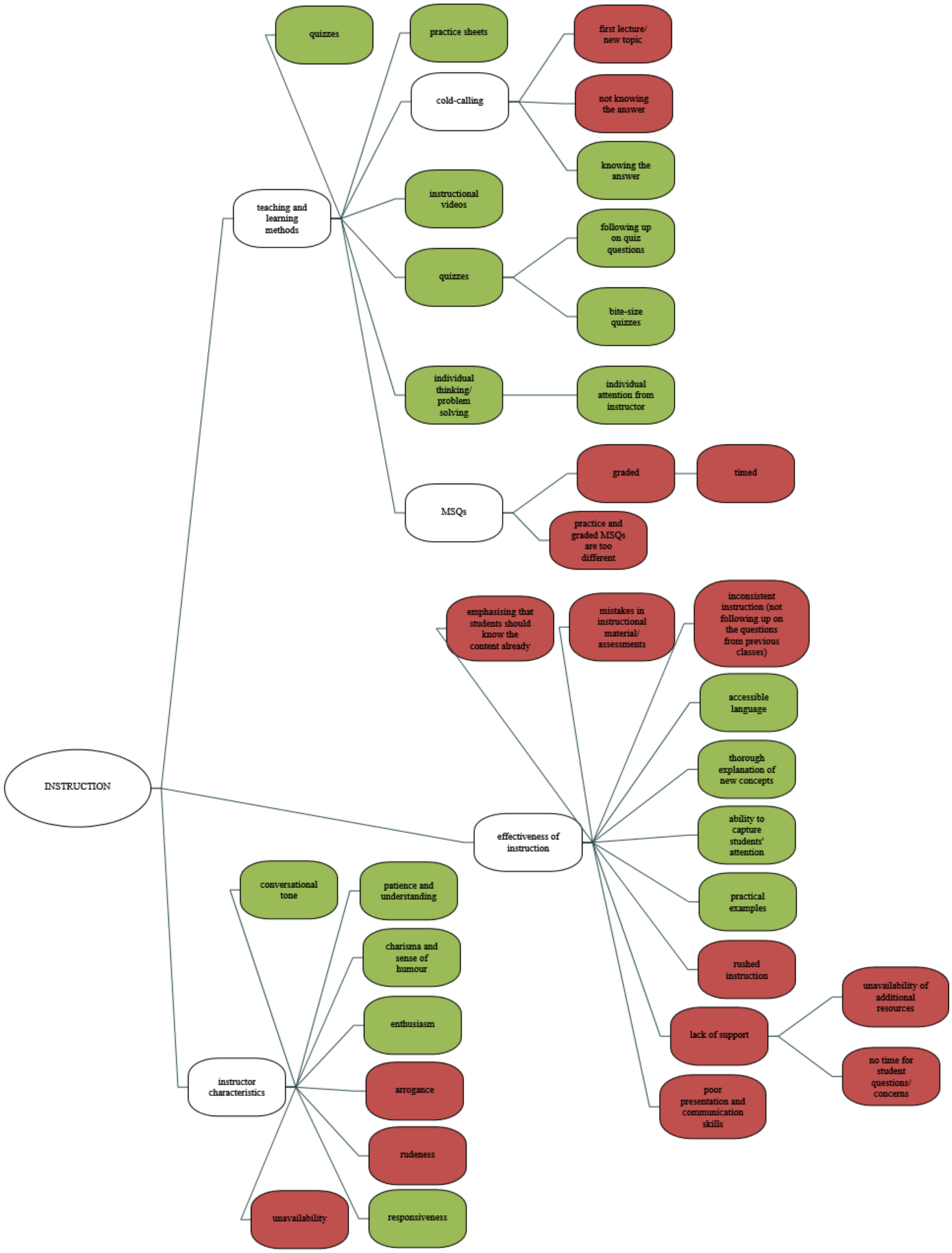
Class Self-Efficacy: Class Material



Class Self-Efficacy: Setting



Class Self-Efficacy: Instruction



Class Self-Efficacy: Performance Achievements