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Science Attitudes of Students Enrolled in an Introductory Environmental Science Course

Rajan Brar, *The University of Western Ontario*

Supervisor: DeCoito, Isha, *The University of Western Ontario*
Co-Supervisor: Mensink, Paul, *The University of Western Ontario*
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Abstract

This study examines attitudes towards science for 198 students enrolled in an introductory university environmental science course. Conceptual frameworks include the theory of planned behaviour and the tripart model of attitudes to assess science attitudes. A quantitative research design, using secondary data, is used to address this purpose. Within this study, *Enjoyment of Science* and *Science Anxiety* factors of attitudes towards science, components of the affective domain of attitude are compared to student gender, faculty, and academic year using a modified mATSI:2 questionnaire. It is found that faculty displays the most significant association with science attitudes, with students from science faculties displaying significantly more positive science attitudes compared to students from nonscience faculties. Male students also display significantly more positive science attitudes compared to female students on two *Science Anxiety* factor items- "*it makes me nervous to even think about science*" and "*it scared me to have to take a science class*". A significant difference is also found between first-year and upper-year students on one *Science Anxiety* factor item- "*No matter how hard I try, I cannot understand science*". Additionally, two distinct clusters are also identified- one cluster displaying positive science attitudes and another displaying neutral and negative science attitudes. Results reveal that the cluster displaying positive science attitudes contains significantly more science faculty students than the cluster displaying neutral and negative science attitudes. Overall, this study demonstrates a relationship between student faculty membership and attitudes towards science for students enrolled in an introductory university environmental science course.

Keywords: science attitudes, attitudes towards science, university students, nonscience, undergraduate study, faculty, gender, academic level, cluster analysis, k-medoid.

Summary for Lay Audience

This study examines the science attitudes of students enrolled in an introductory environmental science course at Western University. Attitude is a major component of behaviour as per the theory of planned behavior. Research displaying differences in science attitudes among different genders, majors and academic years allows teachers to identify which populations need the most support towards developing positive science attitudes. Literature has not well examined science attitudes within post-secondary introductory environmental science courses, which is especially concerning with the ongoing climate crisis around the world and increasing science skepticism in the public. For this reason, it is imperative to examine the attitudes of students within post-secondary introductory environmental science courses so teachers can develop appropriate supports.

Conceptual frameworks include the theory of planned behaviour and the tripart model of attitudes to assess science attitudes within the introductory environmental science course. Enjoyment of science and science anxiety, components of the affective domain of attitude are examined in this study.

This study uses secondary data that is analyzed quantitatively through descriptive, inferential, and exploratory analysis. This involves determining differences between subpopulations based on science attitudes, the identification of clusters from responses to the modified mATSI:2 questionnaire, and examination of relationships between clusters based on demographic data.

This study finds that student faculty has a significant association with attitudes towards science on all modified mATSI:2 items, with science faculty students displaying more positive science attitudes than nonscience faculty students. Student gender and academic year both display significant differences in science attitudes on only a small subset of questionnaire items. Additionally, two clusters are identified, one consisting mostly of nonscience students with neutral and negative attitudes towards science and the second consisting of both science and nonscience students with positive views towards science. The implication of these results is that a subpopulation of nonscience students exhibit more negative science attitudes. It is recommended that this population be explored further to understand the differences between these nonscience faculty students, and that curriculum be created to improve their science attitudes.

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List of Abbreviations

CFI	Comparative Fit Indices
EMPKC	Empirical Kaiser Criterion
K-12	Kindergarten to 12th Grade
MAP	Velicer's Minimum Average Partial
MOOC	Massive Open Online Course
PA	Parallel Analysis
RMSEA	Robust Root Mean Square Error of Approximation
S & T	Science & Technology
SMT	Sequential Chi-Square
SRMR	Standard Root Mean Square Residual
STEM	Science, Technology, Engineering, and Mathematics
TPB	Theory of Planned Behavior

Chapter I: Introduction

Over the last 50 years, a decline in science interest in education settings ranging from elementary to post-secondary schooling has been noted (Osborne et al., 2003; Potvin & Hasni, 2014b). During the COVID-19 pandemic, a noticeable change in attitudes, people's beliefs, and feelings towards science in the population was evident, and viewed as main contributors to vaccine hesitancy (Caso et al., 2022). Recently within education settings, negative science attitudes have even been associated with lower academic science achievement (Ma, 2022). Hence, it is currently more important than ever to ensure students develop positive attitudes towards science.

Students' attitudes towards science, a component of behavioural intention (van Aalderen-Smeets, 2012), have become increasingly negative over the past few decades (Mallow et al., 2010; Rutjens, 2018). The trend of increasingly negative science attitudes is concerning as this poses a challenge for students to succeed in the science classroom. Attitudes towards science have previously been found to be positively associated with academic achievement, suggesting that poor attitudes towards science act as a barrier to student achievement (Mao et al., 2021). The detrimental effects of negative science attitudes extend beyond schooling, with negative science attitudes decreasing the likelihood of students engaging in science, technology, engineering and mathematics (STEM) careers (Blotnicky et al., 2018).

Another concern is the deterioration of student attitudes towards science as they progress through school grade levels. Attitudes towards science have been shown to decline as students progress through elementary and high school (Barmby et al., 2008; Osborne et al., 2003; Potvin and Hasni, 2014a). A series of research reviews from 1975 to 2006 (Barmby et al., 2008; Osborne et al. 2003) and a meta-analysis of the literature from 1982 to 2020 (Mao et al., 2021) demonstrate the consistency and overall decline of science attitude in high school students. Additionally, Potvin and Hasni (2014b) examined 21 ERIC-indexed articles from 2001-2014 on the decline of science and technology interest and found majority of these articles note a decline in science attitude as students progress through kindergarten to 12th grade (K-12) in multiple countries around the world. A marked decrease in science attitude as students progress through K-12 schooling is problematic, as it may hinder student success at the post-secondary level. However, limited research currently examines how science attitudes change beyond secondary school, which is a cause for concern considering recent negative science attitudes, for example vaccination and climate change, in the adult population (Fan et al., 2021; Seddig et al., 2022).

In addition to trends as students progress through school grade levels, specific demographic characteristics have been found to affect science attitude (Osborne et al., 2003). Previous research has found gender to be correlated with science attitudes, in which females display more negative science attitude than males (Barmby et al., 2008; England et al., 2019; Osborne et al., 2003). Students' choice of post secondary major has also been shown to have an impact on science attitudes (Robinson, 2012). Significant science anxiety in humanities and social science students, despite enrollment in non-major science courses has been noted (Udo et al., 2004). However, the relationship between science attitudes and both gender and student major has not been well researched in introductory science courses at the post-secondary level.

Therefore, research specifically evaluating students' attitudes towards science in post-secondary science courses is warranted. Given trends in declining science attitudes over the course of grade school, understanding which populations hold negative science attitudes at the post-secondary level will allow for interventions at the last stage of schooling for many post-secondary students. This will allow educators, teachers, university administration and curriculum designers to intervene and create experiences that promote positive attitudes in science. This is especially important in classrooms not previously examined in the literature, such as introductory post-secondary science classrooms, as it is unclear if previously established relationships can be generalized to these specific contexts.

1.1 Scope, Context, and Purpose

The purpose of this study was to explore post-secondary students' attitudes towards science in an introductory environmental science course. Students of different demographics have been found to have different levels of science attitudes, including anxiety (Gardner, 1975; Osborne et al., 2003; Weinburgh, 1995). Maltar Oken et al. (2022) found that students with higher grades displayed more positive attitudes towards science and had a deeper approach to their learning. For this reason, it is imperative to identify students with negative attitudes towards science so interventions and curriculum changes can be employed to ensure student success. This was done successfully in an environmental science course, with Kazempour and Amirshokoohi (2013) improving attitudes towards science and awareness regarding environmental issues when employing a targeted reform-based course for nonscience major students.

Literature has shown science attitudes decrease as students proceed through K-12 schooling (Osborne et al., 2003), but are also lower at the post-secondary level than in adult learners (Impey et al., 2021). Interestingly, student subject interest may also affect science attitude, as senior students completing art focused education in secondary schools were found to be more anxious about science compared to science focused students (Megreya et al., 2021). Likewise, subject interest and science attitude may also be correlated with course enrollment (Britner, 2008). Whether student attitudes continue to decline or if there is a relationship between student academic focus and science attitude at the post-secondary level, what is evident is that it remains poorly characterized.

At the same time, gender has been found to be a predictor of science attitudes (Weinburgh, 2000). In recent years, female students have displayed higher views of pseudoscience and negative science attitudes than male students (Impey et al., 2017). Science courses at the post-secondary level could be the last opportunity to target students of vulnerable populations, including female students. To foster positive science attitudes at the post-secondary level, it is important to examine how science attitudes differ between year of degree program (academic year), faculty, and gender.

To better examine science attitudes at the post-secondary level, students enrolled in a university level introductory environmental science course were surveyed.

Secondary data, which consisted of 198 student responses to the modified attitudes towards science survey (mATSI:2) were utilized to determine the differences in attitudes towards science. Students' demographic information, including academic year, faculty and gender were included as part of the student survey.

Through this research, I identify subpopulations that may hold negative science attitudes, thereby allowing instructors and curriculum designers to consider opportunities that foster positive science attitudes. Thus, the purpose of this study is to elucidate the relationship between characteristics of students enrolled in an introductory environmental science course and their attitudes towards science. I will also explore curriculum revisions to develop more positive science attitudes at the post-secondary level.

1.2 Statement of Problem

The main elements explored in this study are students' enjoyment of science and their science anxiety, all key components of the affective domain of science attitude. This research explores the affective domain of attitude towards science, which has been thoroughly examined at different levels of grade school education and with students studying different subjects at all levels of education (Tai et al., 2022). Currently limited research has been conducted in this area pertaining to post-secondary education, especially in the post-COVID era. As well, there is a dearth of research examining general science attitudes in introductory science courses. Therefore, in this study I will explore the relationship between science attitudes and student demographics (faculty, gender, and academic year) in a university level introductory science course.

1.3 Positionality

Throughout my experience as a secondary school science teacher, I have noticed drastic differences between students in their attitudes towards science. Many students who aspire to become scientists enjoy engaging with science and are often motivated to succeed. However, students who are not interested in science as a career do not always enjoy participating in the science classroom. Often, I have noticed these attitudes impact how students approach their studies and their academic performance. As a teacher, I believe it is imperative to ensure all students can succeed within the science classroom and beyond. Thus, I believe it is important to ensure all students can develop positive attitudes towards science within the science classroom. This can be achieved by understanding the differences between our students and adapting learning to meet their needs. To accomplish this, I would first like to explore how students differ in their attitudes towards science, and whether there are relationships between different populations and their attitudes towards science. I hope doing so will allow teachers to adapt their practice to meet the needs of identified populations, resulting in more positive science attitudes.

1.4 Research questions

1. What are students' science attitudes in an introductory environmental science course?

   a. How do components of science attitude differ based on gender, faculty and/or year of degree program?

2. Can clusters be identified based on components of students' science attitudes within an introductory environmental science course?
   a. How do clusters differ based on gender, faculty and/or year of degree program?

1.5 Significance of the Study

Through examination of student science attitudes, in addition to identifying potential contributing factors, this research has the potential to enhance curriculum development of science courses at the post-secondary level. Instructors and curriculum designers can use findings from this research to develop curriculum aimed at supporting students from demographics identified as having negative science attitudes. This research will also inform administrators as to which student populations need more support within the sciences, and university-wide support programs could be developed to address the needs of these populations. Thus, findings from this study will result in an increase in awareness of issues related to science attitude within introductory post-secondary science courses. Results of this study can also inform future research on which populations require further support before any policies or curriculum changes are made.

Chapter II: Conceptual Framework

This research study utilizes the theory of planned behaviour (TPB) and a tripartite model of attitudes. Within this chapter, the aforementioned theories are examined. Additionally, previous research examining science attitudes through the lens of these theories is discussed.

Attitude is a factor of behaviour that consists of various positive and negative evaluations of different objects, people, events, or other distinguishable components (Ajzen, 1991). Attitude has been considered a latent variable or construct of behaviour, meaning it cannot be directly measured (Ajzen, 1989). This is an issue that has been extensively studied, with many researchers historically attempting to identify and summarize essential characteristics of attitude (Allport, 1935; Fishbein, 1963; Krech & Crutchfield, 1948; Osborne et al., 2003; Thurstone, 1931; van Aalderen-Smeets et al., 2012; Verplanket et al., 1998). Due to this, many complex definitions of attitude have arisen (Fishbein & Ajzen, 2010).

Attitude is one component of the TPB, coined by Icek Ajzen (1985). This theory is an extension of the theory of reasoned action (Ajzen, 1991), which draws a relationship between the concepts of attitude, intention, and behaviour (Fishbein & Ajzen, 2010). The TPB focuses on an individual's intention to perform a specific behaviour, in which a stronger intention results in a higher likelihood of a behaviour being performed (Ajzen, 1991). This is applied to situations in which an individual can decide to perform, or not to perform, a particular behaviour (Ajzen, 1991). Intention is assumed to capture the motivational factors that cause a behaviour (Ajzen, 1989), making it a widely examined construct of behaviour.

The TPB consists of three independent constructs that determine intention – attitude towards a behaviour, the subjective norm, and perceived behavioural control (Fishbein & Ajzen, 2010). Attitude towards a behaviour, which is examined in this study, determines the degree to which a person has either favourable (positive) or unfavourable (negative) evaluations of a particular behaviour (Ajzen, 1991). The subjective norm is defined as the perceived social pressure an individual may experience to perform a certain behaviour or not (Fishbein & Ajzen, 2010). Finally, perceived behavioural control is the perception people have towards how easy or difficult it is to perform a specific behaviour (Ajzen, 1991). It reflects both previous experience and anticipated obstructions and obstacles (Ajzen, 1989). The TPB also states that a person's perceived behaviour can differ across different situations or actions (Ajzen, 1991). The TPB differs from Ajzen's previous theory of reasoned action due to the addition in of perceived behavioural control (Ajzen, 1991).

Behavioural intention has several components, and ultimately is a product of the attitude towards a behaviour, the subjective norms surrounding the behaviour and perceived behavioural control (Ajzen, 1991). Within the TPB, attitude is a critical component of behaviour and includes our positive or negative evaluations of a particular behaviour (Ajzen, 1991). Generally, the more favourable the attitude towards a behaviour, the stronger the intention to perform the behaviour (Ajzen, 1991; van

Aalderen-Smeets, 2012). The degree of this effect can differ based on situation or behaviour (Ajzen, 1991).

Attitude has often been divided into three main components or a tripartite model – a cognitive component, a conative (behavioural) component, and an affective component (Tai et al., 2022) and can be traced back to the multicomponent view of attitude (Rosenberg et al., 1960, as cited in Fishbein & Ajzen, 2010; Rosenberg, 1956). These three components can be further divided into verbal and non-verbal components (Rosenberg et al., 1960, as cited in Ajzen, 1989). Verbal components include active responses through expression of beliefs, feelings, and behavioural inclinations with respect to any attitude object, while nonverbal components for an attitude object include physiological reactions (Azjen, 1989).

While this tripartite model is widely adopted, considerable correlations between the cognitive component, conative component, and affective components have previously been found (Ajzen, 1989). This has resulted in the creation of a single attitude factor model. One reason for adoption of a single factor model is the fact that attitude cannot be used to directly predict specific behaviours, as attitude measures are often poor predictors of specific behaviours (Ajzen, 1989). When attitudes towards a specific behaviour of interest were previously examined, the conative component was found to better correlate with behaviour than either the cognitive or affective components (Kothandapani, 1971). In a study assessing general attitudes as a predictor for a specific behaviour, Ostrom (1969) found no difference in predictive power between the cognitive, affective, and conative components. In this study, general attitudes toward science are examined, so the tripartite model is also adopted.

This study will focus specifically on the verbal affective domain of attitude, in line with previous literature that focused on the affective domain of attitudes (Gardner, 1975; Koballa, 1988; Potvin & Hasni, 2014b). The affective component refers to mood, emotion, and arousal (Giner-Sorolla, 1999) and includes mood-states with reference to well-defined objects or emotions that can be clearly evaluated (Fishbein & Ajzen, 2010). The affective domain of science attitude refers to a student's emotions and feeling towards science (Ajzen, 2010). This component of attitude will be referred to as "*attitudes towards science*" or "*science attitudes*" in this study and is a common measure in science education research (Osborne et al., 2003; Tai et al., 2022). Attitude is a component of behavioural intention, which in the context of "*attitudes towards science'*" could refer to personal behaviours such as reading science sections of newspapers, television programs, wondering about phenomena in the natural world (van Aalderen-Smeets, 2012), or engaging in or partaking in science education (Pino-Pasternak & Volet, 2018).

The factors of science attitude being examined in this study are identified as *Science Anxiety* and *Enjoyment of Science* within the attitudes toward science construct of the affective domain of attitude. Similar components of science attitudes have previously been used in research, with van Aalderen-Smeets (2012) identifying *enjoyment* and *anxiety* factors in teachers, and Tai et al. (2022) identifying *value and enjoyment* and *anxiety* factors within middle school students.

An important distinction is between attitudes towards science and scientific attitudes. Scientific attitudes are features of scientific thinking, and deal with how an individual approaches understanding of science (Gardner, 1975). Attitudes towards science, however, are the beliefs and feelings about science, and its impacts (Gardner, 1975). Within this study, *"science attitudes"* refers to the latter, *"attitudes towards science"*.

2.1 Applications of the Theory of Planned Behaviour to Science

The TPB has previously been used to examine behaviours related to science and intention towards engaging in science. It has been implemented in two distinct ways to assess behaviour: behaviours related to science in an educational context and those within a public health context.

Education

The TPB has been used to assess behaviours and behavioural intention towards science by assessing their components. These studies have been conducted with teachers and students, demonstrating the effectiveness of a TPB approach for assessing behaviour and behavioural intentions regarding science.

Teachers. Within a population of teachers, a TPB framework has been used to examined behavioural intent for subject-specific teaching. McKim et al. (2018) used an adapted TPB framework including an additional factor of perceived science knowledge to predict intent towards teaching science in agriculture, food, natural resources (AFNR) courses. They found only perceived science knowledge to be significantly related to intention to teach science (McKim et al., 2018). Interestingly, higher perceived science knowledge resulted in lower intention to teach science, suggesting that teachers who have lower perceived knowledge intend to teach science more than those with higher perceived knowledge (McKim et al., 2018).

Students. Student behaviours and behavioural intentions regarding science have also been examined using TPB frameworks, including attitude, perceived behavioural control and subjective norm domains. These have been examined for subject-specific behaviour as well as intention to enroll in future science courses.

Correia et al. (2021) examined higher education student's pro-environmental behavior using a modified TPB approach incorporating an additional factor of environmental knowledge. They found that both environmental attitude and environmental knowledge had no significant impact on students' intention to exhibit pro-environmental behavior, however perceived behavioral control and subjective norm had a significant impact (Correia et al., 2021).

The intention of senior secondary students to enroll in chemistry-related courses was examined using an integrated TPB and Self-Determination Theory (SDT) approach by Ong et al. (2022). Student's autonomy, competency, and relatedness were assessed through SDT frameworks (Butz & Stupinsky, 2017), which were examined in addition to behavioural intention (Ong et al., 2022). Ong et al. (2022) found that the affective component of attitude was the most significant factor, in addition to autonomy and perceived behavioural control, impacting future intentions to enroll in chemistry-related courses.

These studies demonstrate the effectiveness of utilizing the TPB approach in assessing components of behavioural intention in teaching populations. However, they have displayed mixed results as to the main factors influencing behaviours and behavioural intentions, including the role of the affective component of attitude on attitudes towards science (Corria et al., 2021; McKim et al., 2018; Ong et al., 2022). Some researchers note that the affective domain of attitude is not significant (Corria et al., 2021; McKim et al., 2018). This is in line with Ajzen (1989), who states that the affective component may not be the best indicator of behaviour when examining specific attitude. Meanwhile, Ong et al. (2022) found the affective component of attitudes to be a significant predictor of behavioural intention. This indicates a complicated relationship between the affective domain and behavioural intention, which is not fully characterized in the literature.

Public Health

In addition to education, the TPB has been utilized to assess behaviours regarding healthcare and vaccination. Following the COVID-19 pandemic, a noticeable increase in negative attitudes towards science, specifically vaccination, was noticed globally (Caso et al., 2022; Fan et al., 2021; Rzymski et al., 2021; Seddig et al., 2022). Skepticism towards COVID-19, vaccination, and even climate change prevails (Scheitle & Corcoran, 2021). The TPB has been used to examine attitudes towards science regarding aspects of the COVID-19 pandemic in academia (Ammar et al., 2020), with university students (Fan et al., 2021), parents (Caso et al., 2022), and the general adult population (Sedding et al., 2022).

Ammar et al. (2020) examined the psychological impact of COVID-19 on the behavior changes of dental academics around the globe using the TPB. They found key factors of worry and attitude: fear of infection, worries based on professional responsibilities and restricted mobility (Ammar et al., 2020). All three factors were significantly associated with displayed behaviours of more frequent handwashing and avoiding crowded places (Ammar et al., 2020).

Attitudes towards vaccination has been examined using TPB following the COVID-19 pandemic. Fan et al. (2021) examined vaccine uptake intention, including the attitudes towards vaccination, in university students using a TPB model. Attitude was positively associated with uptake of the COVID-19 vaccine, in addition to student's previous uptake of the influenza vaccine (Fan et al., 2021). Attitude towards taking the vaccine was in turn positively influenced by risk perception and knowledge of the COVID-19 vaccine (Fan et al., 2021).

Another important population, parents, was examined by Caso et al. (2022). Caso et al. (2022) examined the psychological factors involved in intentions of Italian parents to not vaccinate their children. They found attitude to be relevant to the intention to vaccinate or not. Negative attitudes towards vaccines were positively associated with a choice of not vaccinating children, which was in turn associated with distal factors of risk perception, trust in healthcare institutions, trust in science and religious morality (Caso et al., 2022).

Finally, Seddig et al. (2022) utilized the TPB to determine vaccine intentions in adults. They examined attitudes, subjective norms, and perceived behavioral control and found attitude towards getting vaccinated to be the only direct predictor of vaccine intention (Seddig et al., 2022). Attitude was significantly impacted by several factors. Vaccine readiness was reduced in participants who held COVID-19 conspiracy beliefs and those skeptical towards vaccines. Additionally, participants who were educated, at risk of serious illness, feared suffering from COVID-19 or had high trust in science were more likely to have positive attitudes towards vaccination (Seddig et al., 2022).

Using the TPB to examine attitudes towards science related to aspects of the COVID-19 pandemic (Ammar et al., 2020) and vaccination (Caso et al., 2022; Fan et al., 2021; Seddig et al., 2022) highlights the importance of positive attitudes towards science. These results, however, do not support Ajzen (1989), who states that the affective component may not be the best indicator of behaviour when examining specific attitudes. This could indicate that attitudes have a greater impact on behaviour as they relate to the COVID-19 pandemic and vaccinations compared to other attitudes towards science. Regardless, it further emphasizes the importance of assessing attitudes towards science in the post-COVID-19 era.

Chapter III: Theoretical Overview and Literature

In this chapter literature pertaining to science attitudes and education are discussed. There are four main areas of importance addressed:

1. Science attitudes, as students progress through schooling.
2. The relationship between student gender and their science attitudes.
3. The relationship between academic faculty and students' science attitudes.
4. Science anxiety, a notable component of science attitudes.

When developing curriculum, it is important to understand how learning differs between students within the classroom. This allows the teacher to develop content to ensure all students are successful and able to meet the course goals. Before this content can be developed, however, the differences between learners must be characterized. This has previously been done in the literature, with Ma (2022) identifying five distinct profiles of middle school students based on their science attitudes: (1) negative science attitudes and low competence, (2) negative science attitudes and low value of science, (3) moderate science attitudes, (4) positive science attitudes or (5) highly positive science attitudes. Profiles have also been identified at the post-secondary level, where Pino-Pasternak and Volet (2018) identified vulnerable, uncommitted, optimal, and promising groups of students based on science attitudes. These distinct profiles could be used subsequently by educators, administrators, or curriculum developers to introduce course content targeting science attitudes.

It is especially important to develop positive attitudes towards science, as research has shown attitude to precede behaviour (Osborne, 2003), and negative science attitudes are an extremely prevalent issue in science teaching (Osborne et al., 2003; Udo et al., 2004; Weinburgh, 1995). On the other hand, positive experiences within the classroom have been associated with better science attitudes, even at the postsecondary level (Robinson, 2012).

Beyond the classroom, prior studies found that the general public holds relatively positive views towards science (European Commission, 2005; Miller, 2004; Office of Science and Technology and The Welcome Trust, 2001). However, in recent years general patterns of science skepticism have emerged, indicating an issue with the public's attitudes towards science (Scheitle & Corcoran, 2021). A few major components of this newly emerged skepticism include the COVID-19 pandemic (Scheitle & Corcoran, 2021), evolution (Pew Research Center, 2015), genetically modified organisms (GMOs) (Scheitle & Corcoran, 2021) and the climate crisis (Pew Research Center, 2016).

Scheitle and Corcoran (2021) investigate how skepticism toward the COVID-19 pandemic relate to skepticism towards other science issues. They found skepticism towards climate change was the lowest, and science skepticism highest for GMOs. It was also found that COVID-19 skepticism was the most highly correlated with both general vaccine skepticism (r=.69) and climate change skepticism (r=.50) (Scheitle & Corcoran, 2021).

The recent increase in science skepticism in the public highlights the importance of developing a positive public attitude toward science, as negative skepticism is becoming prevalent on major science issues (Caso et al., 2022, Scheitle & Corcoran, 2021; Sedding et al., 2022). Science attitudes should be researched further in poorly characterized areas of schooling, including post-secondary education, and should focus on both broad and specific science attitudes to generate a comprehensive picture of science attitudes. Within post-secondary schooling, student academic year, gender and faculty enrollment are large predictors of science attitudes that must be further understood to ensure the development of positive attitudes towards science in all students.

3.1 Attitudes and School Year Progression

A decline in science interest is noted through adolescence (Epstein & McPartland, 1976; Wigfield & Eccles, 1992), beginning in elementary school and accelerating onwards (Osborne et al., 2003). A notable drop for many students occurs when transitioning from elementary to high school (Susilawati et al., 2022). Interestingly, this trend has been found to not continue at the post-secondary level and beyond, with adults being found to have more positive attitudes than university students (Impey et al., 2021). However, there is no consensus on the effect of student grade level and science attitudes, with some research finding conflicting results to the norm (Summers, 2021; Susilawati et al., 2022).

The most prevalent trend within the literature on science attitudes is a decrease in science attitude as students progress through schooling. Potvin and Hasni (2014a) examined research from 2001-2014 on the decline of science and technology interest and noted a decline in science attitude as students age through K-12 education in countries around the world. This trend was also noted by Weinburgh (2000), who found student academic year to be a predictor of science attitudes, with science attitude declining as students progressed through K-12 education. Weinburgh (2000) employed the Attitude Toward Science Inventory (ATSI) and analyzed differences in attitudes towards science between gender, ethnicity, and grade level in middle school students. They suggest the decrease in science attitudes as students progress through K-12 schooling could be due to a shift in how science is taught, moving towards a teaching style that emphasizes memorization and not investigation (Weinburgh, 2000). Notable is the fact that the decrease in science attitude during mandatory schooling seems to be especially prevalent in girls (Kahle & Lakes, 1983).

However, not all research agrees that students' science attitudes decrease as grade level increases. Summers (2021) examined attitudes towards science, behavioural intention to enroll in future elective science courses and the decision (behaviour) to enroll in these courses in American high school students. They administered the Behaviours, Related Attitudes, and Intentions towards Science (BRAINS) survey with grade 9-11 students and interviews with grade 11 students in the subsequent academic year (Summers, 2021). In contrast to other recent literature, they found a small positive effect as student grade level increased, with relatively neutral science attitudes in 9th grade and positive attitudes towards science in grade 11 (Summers, 2021). Susilawati et al. (2022) also found results differing from the norm. They examined science attitude in students aged 11 to 14 across eight elementary schools and eight junior high schools in Indonesia using the Test of Science Related Attitudes (TORSA) instrument (Susilawati et al., 2022). There was no significant difference found in attitudes towards science when comparing elementary and junior high school students, with both expressing positive views (Susilawati et al., 2022). However, they did find a component of science attitudes, *enjoyment of science* was significantly higher for elementary students compared to junior high students (Susilawati et al., 2022). These results emphasize the importance of further examining science attitudes as students progress through schooling, to better characterize the relationship between student academic year and science attitudes.

The complexity of trends between science attitudes and grade level also exists at the post-secondary level and beyond. Science attitudes and science knowledge were examined by Impey et al. (2021) in free-choice learner adults in an astronomy Massive Open Online Course (MOOC), undergraduate nonscience students taking an introductory astronomy course, and science experts. Mixed-methods were employed using three instruments – the National Science Foundation *Science Literacy Survey*, an original questionnaire assessing attitudes and beliefs about science, and additional term-ranking questions for the science experts (Impey et al., 2021). They found that adult learners in the MOOC course had more positive attitudes towards science, lower levels of superstition and pseudoscience, and displayed a higher level of basic science knowledge compared to undergraduate nonscience students. A limitation of this result, however, is that adult learners are often taking the MOOC due to their own self-motivation while the undergraduate students often enrol in an astronomy course to fulfil a graduation requirement (Impey et al., 2021). Finally, both adult and undergraduate students had a limited understanding of science compared to science experts.

While most research note negative attitudes towards science as students age through K-12 education (Epstein & McPartland, 1976; Kahle & Lakes, 1983; Potvin & Hasni, 2014a; Susilawati et al., 2022; Weinburgh, 2000; Wigfield & Eccles, 1992), this relationship has become more unclear in recent years (Summers, 2021; Susilawati et al., 2022). Perhaps this is due to modern best-practice teaching methods utilizing a learner-centered approach rather than a traditional teacher-centered memorization-based approach (Donovan & Bransford, 2005). Recent literature has found learner-centered approaches to be successful at improving students' attitudes (Kazempour & Amirshokoohi, 2013; Walczak & Walczak, 2009). At the same time, it is not well characterized how student attitudes change beyond K-12 at the post-secondary level. While research that has begun to examine this topic (Impey et al., 2021), finding postsecondary nonscience students to have lower science attitudes than adults, science attitudes throughout postsecondary academic years has not been well characterized. Research on this topic would help deepen our understanding of trends in science anxiety as students age through post-secondary schooling.

3.2 Attitude and Gender

In addition to academic year, gender has been commonly noted to be a predictor of science attitudes. Weinburgh (2000) examined how student attitude towards science differed within middle school students. Through an examination of 1381 students, they found that student attitudes differed based on gender, ethnicity, and grade level. Males had an overall more positive attitude towards science compared to females. This is consistent with previous literature on science attitude and gender (Osborne et al., 2003; Wan & Lee, 2017; Weinburgh, 1995), which state boys have more positive attitudes towards science than girls. Interestingly, Weinburgh (2000) also found differences in how males and females differ in their attitude towards science. Males were found to have more positive views of science, motivation in science, higher enjoyment of science and self-concept of science compared to females, who were more positive in their perception of their science teacher and value of science towards society. This highlights that while gender is a predictor of science attitude, the relationship between gender and science attitudes is more complicated than previously thought.

Gender was examined within American college freshman by Machina and Gokhale (2010). Here the effect of introducing science and technology content into a mandatory general seminar course for first-semester freshman students on attitudes towards science and technology were examined. This included "Interest in S & T knowledge, estimates of the social and human value of S & T, ideas about appropriateness of S & T for women, and ideas about the chances that a woman and a man have equal opportunities for success in S & T fields" (Machina & Gokhale, 2010, p. 530). Machina and Gokhale (2010) developed a scale to assess these attitudes, and assessed their results based on changes in factor scores between their intervention and control groups. They found females to have a decline in all attitudes towards science and technology in seminar sections that did not include the science and technology intervention (Machina & Gokhale, 2010). Impey et al. (2017) also examined gender effects on science attitudes in American nonmajor university students and found stronger negative opinions on some science and technology topics and increased belief in pseudoscience by females compared to males.

The aforementioned findings were similar to a study by Ma (2022) which examined science attitudes using the Trends in International Mathematics and Science Study (TIMSS) 2015 data for eight grade students in Hong Kong. They identified five distinct profiles using latent profile analysis: Negative attitudes towards perceived competence in science, negative attitudes towards instrumental value of science and engaging science teaching, moderate attitudes, positive attitudes, and high-positive attitudes. Findings indicate a higher percentage of girls in the *negative attitudes towards perceived competence in science* profile, and a higher percentage of boys in the *moderate, positive,* and *high-positive* attitudes profiles (Ma, 2022). These results echo what previous research (Osborne et al., 2003; Wan & Lee, 2017; Weinburgh, 1995) found, with girls displaying more negative attitudes towards science than boys.

While the idea that females have more negative attitudes towards science compared to males is prevalent in the literature, other results have also been noted. In community colleges, attitudes towards science and perceptions of the laboratory classroom between science and nonscience major students were examined by Robinson (2012). They utilized two instruments to assess attitudes towards science and the laboratory classroom – the Science Laboratory Environment Instrument (SLEI) and Test of Science Related Attitudes (TORSA) (Robinson, 2012). Robinson (2012) found both male and female students displayed positive attitudes towards science, with no gender difference noted when comparing attitudes towards science across faculties. However, they did find females to display a more favourable view towards the laboratory environment compared to males (Robinson, 2012).

There is also recent literature (Susilawati et al., 2022) that challenges this trend, based on research on attitudes towards science and gender and academic year, involving 2023 students aged from 11 to 14 across eight elementary and eight junior high schools in Indonesia. The Test of Science Related Attitudes (TORSA) instrument to measure science attitudes was utilized and findings indicate that female students have more positive attitudes and interest towards science (M=3.78; SD=0.46) compared to males (M=3.52; SD=0.54), with a medium effect size (d=0.52). Both males and females, however, had scores indicating positive attitudes towards science (Susilawati et al., 2022).

The interaction of gender and science attitude also differs depending on the subject being examined. In a review of literature, Gardner (1975) found differences between gender and science interest, with boys being more interested in the physical sciences and girls more interested in both biological and social sciences. DeWitt et al. (2019) also found physics as a subject to be more male dominated, leading to females deciding not to pursue physics as a subject of study. Interestingly Weinburgh (1995), through a meta-analysis of research, found wider gaps between male and female students within earth sciences and general sciences rather than biology and physics.

This indicates that course subject is one predictor of the differences in science attitude between males and females.

Overall, while prevailing literature does display a gender difference between male and female students on science attitude, mixed results still exist. It seems that gender differences could be due to the subject examined, however this requires further inquiry to characterize this phenomenon. It is also unclear what the differences in general science attitudes are between male and female students at the post secondary level. It is important to note, however, that these studies only identify male or female when examining gender, excluding a large group of students who do not identify with these genders (David et al., 2021).

3.3 Attitude and Faculty

In addition to grade level and gender, additional demographic information that impacts attitudes towards science is student faculty. This topic has been examined by Robinson (2012) in post-secondary students. However, literature examining science attitudes is limited, with most recent literature focusing on either specifically nonscience major students (Kazempour & Amirshokoohi, 2013; Walczak & Walczak, 2009) or science anxiety (Megreya et al., 2021; Udo et al., 2004). Literature on nonscience major students focuses on improving the science attitudes of nonscience major students, rather than identifying which majors exhibit negative science attitudes.

Robinson (2012) examined differences between science (allied health, STEM) and nonscience majors in a biology course at a community college using two instruments -

the Science Environment Laboratory Inventory, and the Test of Science Related Attitudes. Compared to allied health and STEM majors, nonscience majors displayed more negative attitudes regarding adoption of scientific attitudes, scientific inquiry, and enjoyment of science lessons (Robinson, 2012). Findings indicated that nonscience major students had a less positive view towards inquiry-based activities and conducting experiments compared to STEM and allied health majors (Robinson, 2012). Nonscience majors, however, displayed no significant differences compared to allied health or STEM majors on their views of the laboratory environment, with all being positive (Robinson, 2012). Researchers and academics have previously attempted to improve nonscience major students' attitudes towards science through various targeted courses or interventions. As is recommended by Robinson (2012), many of these courses focus on nonscience major students.

In a previous study (Walczak & Walczak, 2009) aimed at combatting this issue, attitudes towards science were examined for 46 nonscience major students before and after taking a general education chemistry course designed for nonscience major students. This course involved a news assignment designed to increase science literacy through independent research and the analysis of information reliability from research sources (Walczak & Walczak, 2009). Walczak and Walczak (2009) employed a mixed-methods approach using items from the View of Science-Technology-Society (VOSTS) survey and qualitative interviews. They found significant changes in attitudes towards science related to course components, especially regarding the news assignment (Walczak & Walczak, 2009). Items that did not have significant differences were not highly related to the course content. Students displaying a positive attitude towards science stated that connections to real-world factors displayed in the course and the news assignments as reasons for these attitude changes (Walczak & Walczak, 2009). This displays the importance of connecting content to student interest when developing nonscience major courses.

The effect of a reform-based undergraduate environmental science course for nonscience major students and elementary teacher candidates on environmental science knowledge and attitudes was examined by Kazempour and Amirshokoohi (2013). Reform-based in this study refers to a more active learning style, and less focus on content. This course targeted nonscience major students, while also shifting away from a memorization-based curriculum that has been speculated to cause decreases in positive science attitudes (Weinburgh, 2000). In the study by Kazempour and Amirshokoohi (2013), content analysis of an initial information sheet, three reflective journals and a focus group session following the course were analysed. Following the course, they found an improvement in environmental issues and concept awareness and an increase in awareness of the impact of students' daily lives on the environment. Students also developed more positive attitudes towards environmental issues and began working to resolve those identified issues (Kazempour & Amirshokoohi, 2013). This article suggests that traditional course structures may be hindering the development of positive attitudes towards science for nonscience major students.

Overall, while Robinson (2012) does note an association between faculty and science attitudes, research on the association between science attitudes and student faculty is limited. However, there are researchers and educators currently aiming to improve science attitudes in nonscience major students. Kazempour and Amirshokoohi (2013) examined the impact of a nonscience major environmental science course and found the course to have an impact on the development of positive attitudes in students. Walczak and Walczak (2009) found real-world factors and their news assignment to also have an impact on the development of positive science attitudes. In my study, student faculty is examined further within an introductory environmental science course, which includes a focus on science literacy, similar to Walczak and Walczak (2009). In the course examined in this study, 40% of the overall course grade was allocated to scientific literacy and communication skills. Further characterization of science attitudes for nonscience majors will allow for curriculum changes and the development of more successful “nonscience major science courses” that can potentially impact student attitudes in the future.

3.4 Science Anxiety

One of the key components of science attitude examined in my study is science anxiety. Science anxiety was coined by Mallow in 1977 as “a debilitating interaction of emotion-fear, with cognition-science learning” (Mallow et al., 2010, p. 1). Mallow (1978) describes science anxiety as having negative consequences including mental paralysis on science exams, anti-science attitudes, science illiteracy, the avoidance of hard science careers, and discomfort with assistive technology by medical professionals. Science anxiety has been shown to cause students to perform poorly in the classroom (Udo et al., 2004) and on exams (Alvaro, 1978; Megreya et al., 2021). Recently, literature also found that science anxiety is associated with science achievement for eighth grade students on science achievement tests (Cho & Aye, 2020). Therefore, science anxiety is associated with academic achievement on science assessments. The causes of science anxiety are numerous, including but not limited to past experiences in science, science-anxious teachers in previous schooling, a lack of appropriate role models, stereotyping of gender and race, as well as stereotypes of scientists within popular media (Udo et al., 2004). Science anxiety has been found to differ between genders (Cho & Aye, 2020; Mallow, 1994; Megreya et al., 2021; Udo et al., 2004), majors (Megreya et al., 2021; Udo et al., 2004) and the type of science concepts being examined (Britner, 2008).

Gender is often cited to be a predictor of science anxiety (Cho & Aye, 2020; Mallow, 1994; Udo et al., 2004). This relationship was demonstrated by Mallow (1994) through a binational study examining science anxiety in American and Danish students aged 17 and up. They found gender to be the second strongest predictor of science anxiety in American and Danish women following nonscience anxiety, and females displayed significantly more science anxiety than males (Mallow, 1994). This finding persists over time, with recent research finding gender to be a leading predictor of science anxiety (Cho & Aye, 2020; Udo et al., 2001) along with nonscience anxiety (Udo et al., 2004). Within this literature, females are found to have greater science anxiety than males (Mallow, 1994). However, despite this consistency over time, no literature examines gender beyond binary male-female labels, making generalization of results towards populations that do not identify as male or female difficult. Previous research by Wilkinson et al. (2021) has found educational outcomes, including math test scores, course failures, math course attainment and postsecondary enrollment to differ between cis-gender and gender-diverse youth.

Student faculty membership or chosen major are also associated with science anxiety levels. Udo et al. (2004) examined students of different majors enrolled in general education courses for nonscience students. They found major, in this case humanities or social sciences compared to other majors, to be a third significant predictor of science anxiety. This parallel results by Mallow (1994) that being a nonscience major student was a predictor of science anxiety. In the study by Udo et al. (2004) in particular, humanities and social science majors were significant predictors of science anxiety regardless of gender, even though all students were enrolled in general education science courses for nonscience majors. This suggests that courses for nonscience majors may not be effective at reducing the gap of science anxiety between students of particular science and nonscience majors (Udo et al., 2004). While math and science majors displayed the lowest science anxiety levels, within these majors' females were still more science anxious than males (Udo et al., 2004). In recent literature, Megreya et al. (2021) found arts focused students in year 11 and 12 of K-12 education to be more anxious about science than science focused students.

Beyond the major of a student, science anxiety can differ depending on the science concepts examined. Britner (2008) examined self-efficacy, science anxiety and achievement in high school students studying science (n= 502). They found differences in all three variables between earth sciences, life sciences and physical science courses. Within life science courses, females had higher grades and the same self-efficacy compared to males, and higher levels of science anxiety (Britner, 2008). In contrast, females in the physical sciences had the same grades and self efficacy as males, but once again had higher science anxiety. Interestingly, science anxiety for females in Earth science courses did not show strong science anxiety, but they had higher grades and the same self-efficacy as males (Britner, 2008). While this supports previous research regarding the interaction of gender and science anxiety, it also displays that the relationship between the subject of study, science anxiety and gender is complicated.

While research examining science anxiety in life science, physical science and earth science courses exist, there is a lack of research characterizing the relationship between science anxiety and student demographic backgrounds in environmental science courses. Research on attitudes towards environmental issues (Bybee, 2014) found that boys score higher than girls on awareness of environmental issues, while girls indicated greater concern than boys for environmental issues. However, this research does not examine attitudes towards science for students enrolled in introductory university environmental science courses.

Chapter IV: Methodology

In this study I assess attitudes toward science of university students enrolled in an introductory environmental science course. In this chapter, the research design utilized is highlighted, as well as context, secondary data sources, procedures for data analysis and ethical approval.

4.1 Research Design

A quantitative research design was utilized in this study. Creswell and Creswell (2014) define quantitative research as an approach where the relationship among variables is used for testing objective theories. Using a quantitative approach for this study allows for examination of the relationship between student demographics and science attitudes, determining groups of students to be clustered based on commonalities of their survey responses and quantifiable results that can be used to inform both educators in their practice and future researchers.

This study uses secondary data gathered from previous research conducted by Dr. Paul Mensink (Mensink, 2022). This study was able to utilize the data collected by Mensink (2022) to address identified research questions regarding the science attitudes of students enrolled in introductory environmental science courses. As the analyzed data was recently collected within a science class at a Canadian university and includes both demographic information and data on attitudes towards science, it was deemed appropriate for the purposes of this study. The data sources for this study include results of the mATSI:2 questionnaire measuring the components of *Science Anxiety* and *Value and Enjoyment of Science* as well as diagnostic data (faculty, gender, and academic year). This data was collected in a diagnostic survey by Mensink (2022) prior to interventions being implemented.

The utilization of secondary data to address research questions within this study has both advantages and disadvantages. Advantages of using secondary data analyzed over primary data include easy accessibility and inexpensive utilization of data. Within this study, ethical approval was previously granted, aiding the accessibility of the data. However, two main disadvantages exist for the secondary data collected by Mensink (2022). First, it utilizes a novel instrument to assess science attitudes, the mATIS:2 survey, requiring validity and reliability to be re-assessed. Second, it is missing demographic information, such as racial identity, indigeneity, and age, that could provide useful insights into the relationship between science attitude and student demographics. Thus, utilizing secondary data allows for the effective data analysis on major components of science attitudes in an introductory environmental science course.

4.2 Participants and Setting

Approximately 198 students (male=57, female=129, genderqueer=1, unidentified =10) enrolled in an introductory environmental science course at Western University during the winter 2022 semester participated in the initial study. This study took place before an online class in the second half of the course. At this point in the course students were already exposed to course material. Responses were also collected during the COVID-19 pandemic, which could impact results of the study.

4.3 Data Sources

Data was collected utilizing the first survey administered by Mensink (2022), including:

1. The mATSI:2 questionnaire
    a. The mATSI:2 questionnaire is a 9-item questionnaire originally developed by Tai et al. (2022) as an instrument for measuring science attitudes. Responses are measured on a 5-point scale, ranging from 1-strongly disagree, 2-disagree, 3-neutral, 4-agree and 5-strongly agree. The mATSI:2 has a reduced number of items compared to the original modified Attitudes Towards Science Inventory (mATSI), which has been widely tested. While the mATSI:2 survey was developed in a sample of middle school students, the former mATSI survey has been used in a variety of different populations (Tai et al., 2022). Through factor analysis, the factors *science anxiety* and *value* and *enjoyment of science* were identified in this study. The distribution of questions within these factors can be found in Table 1.
2. Student demographic information
    a. Demographic information including student gender, faculty and year of academic study were collected in the initial study.

Table 1

Distribution of Survey Items Among Key Factors in the mATSI:2 Questionnaire

Item Number	Question
	Value and Enjoyment of Science Factor
Q4	Science is useful in helping to solve the problems of everyday life
Q5	Science is helpful in understanding today’s world
Q7	Science is something I enjoy very much
Q8	I like the challenge of science assignments
Q9	I have a real desire to learn science
	Science Anxiety Factor
Q1	It makes me nervous to even think about science
Q2	I feel tense/nervous when someone talks to me about science
Q3	It scared me to have to take a science class
Q6	No matter how hard I try, I cannot understand science

Note. mATSI:2 questionnaire developed by Tai et al. (2022)

4.4 Study Procedure

This study focuses on analysing secondary data that was collected by Mensink (2022), while adhering to the letter of information and consent signed by participants in previous research. Participant privacy and confidentiality are protected within this study. Upon collection of data from Mensink (2022), data was analyzed using RStudio and SPSS software.

Previous Study

In the initial study by Mensink (2022) students participated in a learning activity that focused on both scientific and quantitative skills. The purpose of this research was to determine how two different introductory activities impacted students on a subsequent activity (Mensink, 2022). Participants were randomly assigned to two experimental groups (Mensink, 2022):

1. Augmented reality
2. Without augmented reality

Following randomization students completed an initial survey that collected demographic information (student gender, faculty, and academic year), and the mATSI:2 questionnaire developed by Tai et al. (2022). Within this instrument student science attitudes were assessed. Data from this survey is examined in the current study. Thus, the only data analyzed in this study is that collected prior to any interventions.

4.5 Data Analysis

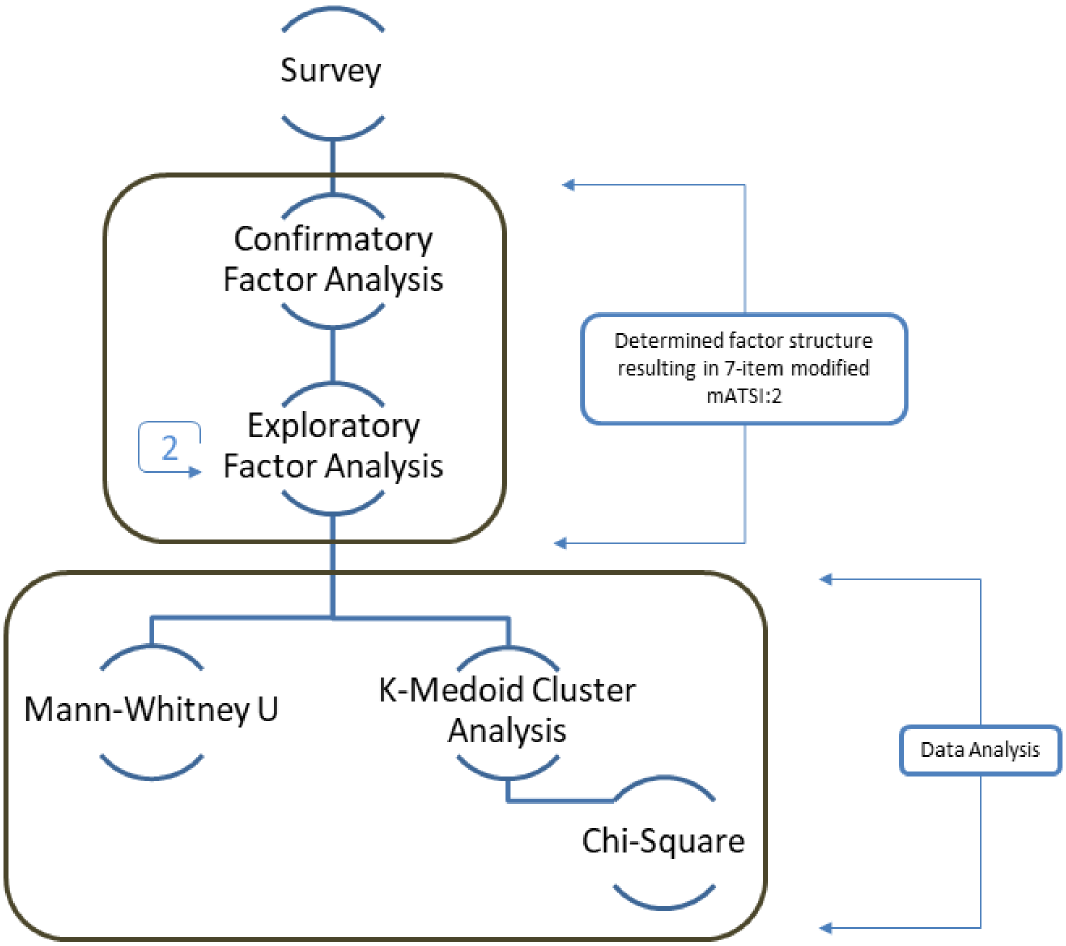
Data analysis includes demographic information and responses to the mATSI:2 attitudes towards science questionnaire. Following collection of quantitative data, responses were transferred to both SPSS and RStudio statistical software programs. Here differential, inferential, and exploratory data analysis was conducted (Figure 1).

Differential and inferential statistics are used to analyse secondary data within this study. Descriptive statistics, one of the two major forms of data analysis, include measures of frequency distributions, measures of central tendency measures of position and measures of dispersion (Kaur et al., 2018). They describe and summarize raw data from samples or populations, but do not make further inferences (Kaur et al., 2018). In this study, participants' demographics are explored using descriptive statistics.

As the original mATSI:2 scale was developed and implemented in a sample of middle-school students (Tai et al., 2022), validity and reliability must be re-established for use in an introductory university level science course. Initially, this is done using confirmatory factor analysis (CFA). CFA is used to evaluate structural validity to determine if items on an instrument are related to hypothesized latent variables and includes verifying factors identified in previous research (Harrington, 2009). It can also be used to estimate reliability of a scale (Harrington, 2009). Detailed methods for how CFA and EFA were conducted in this study can be found in Appendix B. In this study, factors are identified based on items included in existing subscales of *Value and Enjoyment of science,* and *Science Anxiety* identified by Tai et al. (2022).

Figure 1

Flowchart Displaying Data Analysis Conducted Following Collection of Survey Results



Two factors were identified using EFA - *Enjoyment of Science* and *Science Anxiety.* Two items were removed from the questionnaire for analysis in this study, both of which examined the value of science. This reduced the original *Value and Enjoyment of Science* factor to the *Enjoyment of Science* factor. Following identification of factors, inferential statistics are used to make inferences about the population of students taking introductory environmental science courses. This is tested using the Mann-Whitney U test- a non-parametric test that determines whether the cumulative distributions of two random variables are equal or unequal (Mann & Whitney, 1947). Here the null hypothesis is tested that these distributions are equal ($H_0\colon \Pr(X < Y) = \Pr(X > Y) = 0.5$). This is testing the probability that a randomly chosen X value being greater than a randomly chosen Y value is different than a randomly chosen X value being smaller than a randomly chosen Y value (Mann & Whitney, 1947). Here all items are ranked, and the "rank mean" is compared between two different groups. If these two "rank means" are statistically significantly different, then the null hypothesis is rejected (Mann & Whitney, 1947). Eighteen different Mann-Whitney U tests are performed, comparing the seven items examining science attitudes with gender, faculty, and academic year. These evaluate if students differ in their attitudes towards science based on demographics.

In addition to descriptive statistics, cluster analysis, a form of exploratory analysis, is used to find distinct subpopulations among the data. Cluster analysis is used to identify patterns in *Science Anxiety* and *Enjoyment of Science* factors of science attitudes based on questionnaire items examined. Two clusters were identified following cluster analysis. A more detailed examination of clustering techniques used can be found in Appendix B. Further inferences are made using inferential statistics, where causative, associative, and other analysis of data is conducted (Kaur et al., 2018). Within this test, inferential statistics conducted on cluster results includes chi-square tests to determine differences between identified clusters.

Pearson's Chi-Square

Following cluster analysis, chi square analysis is used to determine if there an association between the clusters and gender, faculty, or academic year. Chi-square analysis is a non-parametric bivariate statistical test that allows you to represent the relationship between two independent categorical (nominal) variables (McHugh, 2013). The chi-square (X^2) examines the discrepancy between expected values and observed values (McHugh, 2013) using the formula:

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

Here X^2 is the chi-square test statistic, f_o is the observed frequency of a cell and f_e is the expected frequency of a cell. An alpha value of 0.5 is used as the cut-off to determine significance, indicating that we can be 95% confident in the results and that there is a statistically significant association between categorial variables. Chi-square does, however, have limitations, as it cannot assess direction or strength of a relationship (McHugh, 2013).

4.6 Ethical Concerns

Ethical approval was not needed to access the secondary data used in this study. In the initial study, participants consented to having their data retained for up to seven years, and agreed their data could be used beyond the scope of the study by other researchers. Anonymity and confidentiality were protected for all participants through the creation of a unique code for each responder. This unique code does not allow identification of the individual participants, thus allowing participants to withdraw their data at any point prior to publication of research.

Chapter V: Findings

The purpose of this study is to elucidate relationship(s) between student characteristics and their attitudes and beliefs towards science in an introductory environmental science course. This study aims to identify demographics that should be the focus of curriculum changes aimed at developing a more positive science attitude at the post-secondary level. In this chapter, I address the following research questions:

1. What are students' science attitudes in an introductory environmental science course?
    a. How do components of science attitude differ based on gender, faculty and/or year of degree program?
2. Can clusters be identified based on components of students' science attitudes within an introductory environmental science course?
    a. How do clusters differ based on gender, faculty and/or year of degree program?

5.1 Survey Findings

Demographic Information.

One hundred and ninety-eight participants participated in this study. The survey utilized gathered data on the gender, faculty, and academic year of students. Prior to analysis of data, participants were excluded based on unspecified answers on mATSI:2 questionnaire items. This resulted in the analysis of 197 student responses. The demographic information of participants can be found in Table 2.

Within this sample, a majority (65.48% or 129) of participants were female. Additionally, 28.83% of participants were male (n=57), 0.51% genderqueer (n=1) and 5.08% were unable to be identified due to their responses (n=10). In this study, participants who selected the genderqueer and unidentified answers were not analyzed in Mann-Whitney U or Chi-Square tests examining the relationship between science attitudes and gender but were still included in the cluster analysis. This is due to low sample size making it not possible to conduct Mann-Whitney U or Chi-Square tests on students who did not identify as male or female. However, previous research recommends that, despite potentially low sample sizes, gender identities that do not fit into male-females labels are included in data analysis where possible (Kennedy et al., 2020). For this reason, all responses are included in descriptive statistics of the entire study and for cluster analysis.

Within this study, student faculties were simplified to science (29.95%) and nonscience (70.05%) faculties. Included within the science faculties is the Faculty of Science, Faculty of Health Sciences, and Schulich School of Medicine & Dentistry at Western University. The nonscience faculties consist of the Faculty of Arts and Humanities, Faculty of Social Sciences, Faculty of Information and Media Studies and the Don Wright Faculty of Music at Western University.

Table 2

Demographic Information of Participants

Variables	Frequency	Percent
Faculty		
Nonscience	138	70.05%
Science	59	29.95%
Total	197	100%
Identified Gender		
Male	57	28.83%
Female	129	65.48%
Genderqueer	1	0.51%
Unidentified	10	5.08%
Total	197	100%
Year of Degree Program		
First-Year	150	76.14%
Upper-Year	45	22.84%
Unidentified	2	1.02%
Total	197	100%

Note. The faculties identified (Faculty of Science, the Faculty of Health Sciences, Schulich School of Medicine & Dentistry, Faculty of Arts and Humanities, Faculty of Social Sciences, Faculty of Information and Media Studies and Don Wright Faculty of Music) have been collapsed into “nonscience” and “science” faculties. Year of degree program (1, 2, 3, 4 and 5) are collapsed into First-Year and Upper-Year categories.

Greater than half of the participants were first-year students (76.14%), with the remaining being upper-year students (22.84%) or unidentified (1.02%). Upper-year students are defined as students in any academic year other than their first academic year. Unidentified responses were included in cluster analysis but not in Mann-Whitney U or Chi-Square tests examining the relationship between academic year and science attitudes.

mATSI:2 Survey Findings

The mATSI:2 survey, consisting of nine items, was used in this study to determine student's attitude towards science. Within the study that devised this scale (Tai et al., 2022), items were divided into two key factors based on exploratory factor analysis results (Table 1). The two factors identified by Tai et al., (2022) were *Science Anxiety* and *Value and Enjoyment of Science.*

Prior to conducting analysis using responses from these 9 items, validity and reliability needed to be re-established. The original study conducted tests in a sample of middle school students, however the current study examines a population of university-aged students. While the original ATSI was developed and tested in university-aged students, and the mATSI has been used in multiple different populations (Tai et al., 2022), the mATSI:2 has only been implemented for middle school students. To assess validity and reliability of the mATSI:2 survey instrument in this new population, confirmatory factor analysis (CFA) and exploratory factor analysis (EFA) were conducted.

5.2 Confirmatory Factor Analysis (CFA) Findings

First, confirmatory factor analysis (CFA) is performed to assess validity of subscales *Science Anxiety* and *Value and Enjoyment of Science*. Before conducting CFA, assumptions are tested. No items were missing values, and good factorability was established using the Kaiser-Meyer-Olkin (KMO) factor adequacy (0.86) (Tabachnick & Fidell, 2013).

Next, univariate, and multivariate normality are tested. Univariate normality is tested using Shapiro-Wilk normality tests for all 9 items (Table 3). All items are found to violate assumptions of univariate normality ($p<0.05$). Histograms for all items are found in Figure 2, visually displaying non-normality. Mardia's multivariate normality test is also conducted via the psych package in RStudio and displays significant skewness ($p=3.330669e-16$) and kurtosis ($p=4.758416e-13$). This indicates multivariate non-normality (Harrington, 2009).

Next, multicollinearity is tested by examining the correlation matrix with the purpose of ensuring the variables are not too highly correlated (Knekta et al., 2019). Multicollinearity is deemed problematic if the values are close to -1 or +1. The highest value was found was 0.76, meaning multicollinearity is not problematic. Results can be found in Figure 3. Bartlett's test of sphericity is also conducted and found significant ($p=4.604489e-152$), indicating that intercorrelation exists in the dataset, and is different than the identity matrix (Garson, 2022).

Table 3

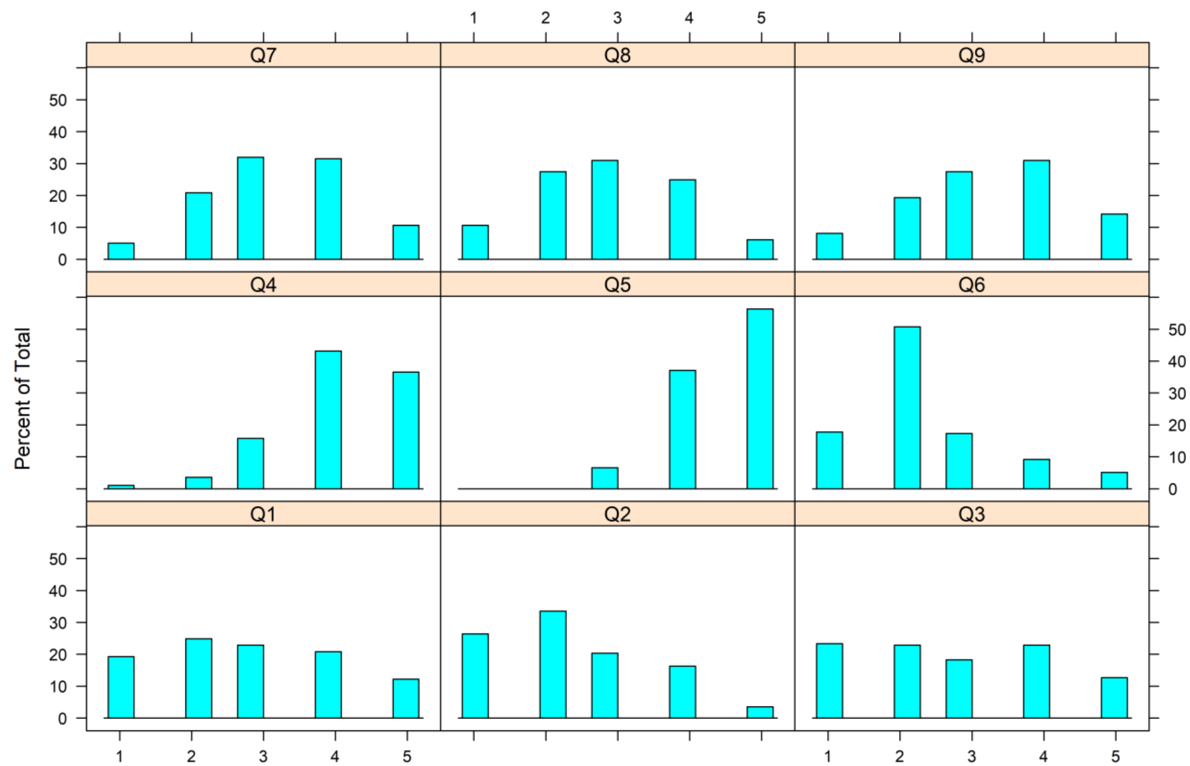
Results of Shapiro-Wilk Tests for mATSI:2 Items

	Statistic	Sig
Q1	0.90309	4.946e-10***
Q2	0.88098	2.295e-11***
Q3	0.88906	6.726e-11***
Q4	0.82039	2.544e-14***
Q5	0.71369	2.2e-16***
Q6	0.9105	1.531e-09***
Q8	0.91331	2.386e-09***
Q9	0.91054	1.541e-09***

***$p < .001$

Figure 2

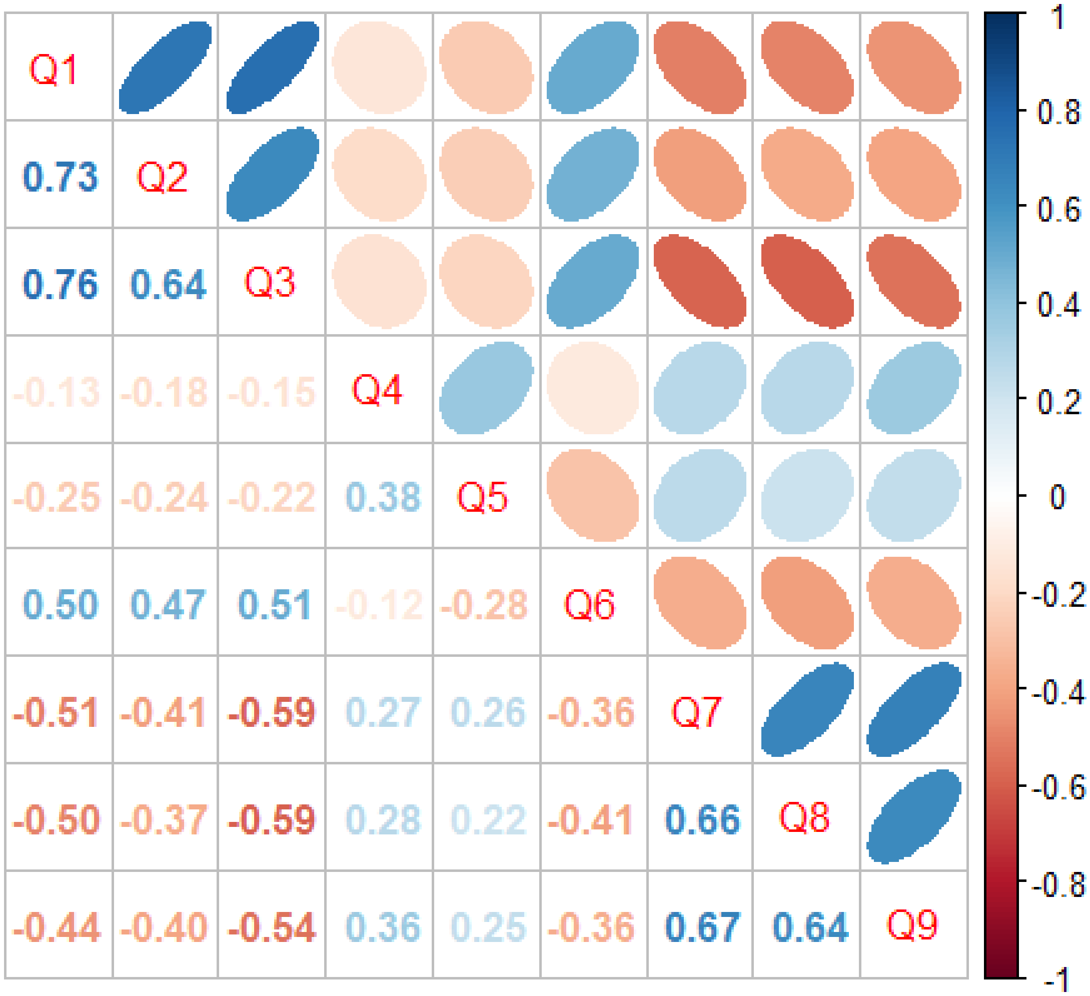
Histogram Displaying the Distribution of mATSI:2 Responses



Note. Displays the percent distribution of mATSI:2 survey responses from 1-Strongly Disagree, 2-Disagree, 3-Neutal, 4-Agree and 5-Strongly Agree

Figure 3

Correlation Matrix of mATSI:2 Items



Note. A correlation matrix examining multicollinearity betweem mATSI:2 items, with values close to -1 or +1 indicating multicollinearity. Ellipses represent positive (blue) or negage (red) correlation.

After assumptions testing, confirmatory factor analysis (CFA) is conducted using the subscales S*cience Anxiety* and *Value and Enjoyment of Science* presented by Tai et al. (2022). Due to multivariate non-normality, diagonally weighted least squares (WLSMV) is used as the estimator, as it does not assume normality and is often used in categorical and ordinal data analysis (Harrington, 2009), which our dataset consists of.

Initially, the CFA chi square test is found to be significant (X^2=117.071, df=26, p<0.001), meaning the CFA model is supported. However, CFA chi-square is not always reliable (Knekta et al., 2019), so additional model indices were run. For the additional model indices, comparative fit indices (CFI) are 0.915, robust root mean square error of approximation (RMSEA) 0.135 and SRMS 0.071. While the standard root mean square residual (SRMR) results suggest the model fits with the two-factor CFA (SRMR<0.08), the RMSEA and CFI do not. Cut offs for these values when determining good fit for the model are RMSEA <0.06 and CFI >0.95 (Knekta et al., 2019).

Cronbach's alpha is examined for both subscales to determine internal consistency reliability (Cronbach, 1951). *Science Anxiety* (α=0.86) and *Value and Enjoyment of Science* (α=0.779) subscales both displayed alpha values of >0.70, indicating acceptable reliability (Tavakol & Dennick, 2011).

Values for standardized factor loadings squared are examined (Table 4), given conflicting results whether the validity of the model was supported. Values below the 0.5 cut-off indicate poor fit, with three items Q4 (0.207), Q5 (0.273) and Q6 (0.442) displaying low factor loadings, indicating items do not load well on their subscales.

Table 4

Standardized Factor Loading Scores (R^2) for mATSI:2 Responses

Q1- It makes me nervous to even think about science	0.807
Q2- I feel tense/nervous when someone talks to me about science	0.659
Q3- It scared me to have to take a science class	0.835
Q4- Science is useful in helping to solve the problems of everyday life	0.207
Q5- Science is helpful in understanding today's world	0.273
Q6- No matter how hard I try, I cannot understand science	0.442
Q7- Science is something I enjoy very much	0.756
Q8- I like the challenge of science assignments	0.700
Q9- I have a real desire to learn science	0.676

Note. Factor loading scores where values below 0.5 indicate poor fit with respective subscales (Knekta et al., 2019)

Correlation residuals, which indicate the difference between the matrix of the original dataset and that implied by the CFA (Bandalos & Finney, 2010), are also examined to further inspect the model (Knekta et al., 2019). Analysis of correlation residuals indicates a large residual between items Q4 and Q5 (0.272). This indicates a relationship not captured by the model is present (Knekta et al., 2019), and that there is potentially more or less than two factors present within the data.

5.3 Exploratory Factor Analysis (EFA) Findings

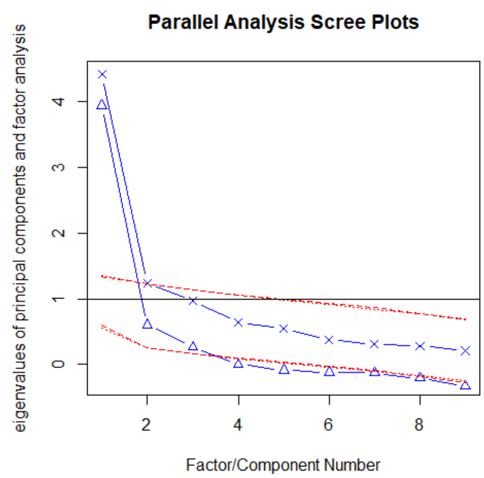
The model presented by Tai et al. (2022) may not be valid within the examined population, indicating that different factors may be present. For this reason, exploratory factor analysis (EFA) was performed on the dataset to determine a more appropriate model.

To determine the number of factors to test using EFA, parallel analysis (PA), Velicer's minimum average partial (MAP), sequential chi-square (SMT) and empirical Kaiser criterion (EMPKC) tests are conducted (n=197). Within PA, eigenvalues from the dataset are compared to eigenvalues from a random dataset. The number of factors or components are found where the real eigenvalues exceed the simulated eigenvalues, resulting in the identification of a both one and three factor solution (Figure 4). Following this, MAP, SMT and EMPKC tests are conducted using Pearson correlations through the EFA. The MAP test identifies a one factor solution, the SMT test identifies a three-factor solution, and the EMPKC test is returns a one factor solution. Based on these results, both a one and three factor solution will be tested using EFA.

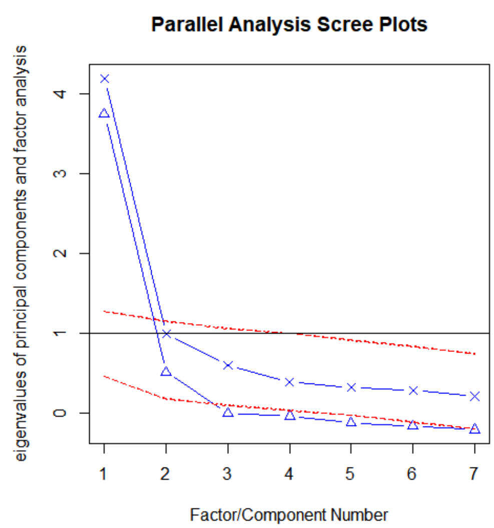
Figure 4

Principal Axis Factoring for the First and Second EFA

First EFA



Second EFA



Note. Factors are identified where eigenvalues for the actual factor analysis factor analysis data (Triangle) or principal component analysis analysis data (X) exceeds the similated factor analysis data or simulated principal component analysis data represented by red dotted lines.

First EFA

EFA was first conducted is a three-factor solution. As the data examined is both ordinal and non-normal, principal axis factor (PAF) is used as the estimator for EFA. Within this study, promax rotation is used for the 3-factor solution and unrotated loadings are examined for the one-factor solution. The pattern matrices for the rotated three-factor solution can be found in Table 5, and the one-factor solution in Table 6. Previous guidelines indicate pattern coefficient loading values (λ) should between 0.40 and 0.70 to be considered good cutoff-values (Matsunaga, 2010). Within this paper, 0.45 will be used as the cut-off value for significance as this has been previously identified as a cut-off value for use with a sample size between 150 and 199 (Hair, 2006).

Within the three-factor solution (Table 5), one factor emerges with two items displaying excellent factor loadings ($|\lambda|>0.71$), one items displaying good loading ($|\lambda|>0.55$) and one item displaying fair loading ($|\lambda|>0.45$) (Tabachnick & Fidell, 2013). Another factor emerges with three items displaying excellent factor loadings ($|\lambda|>0.71$) (Tabachnick & Fidell, 2013). A final factor emerges with two items displaying good factor loadings ($|\lambda|>0.55$) (Tabachnick & Fidell, 2013). There is no significant cross-loading between items ($|\lambda|<0.45$). Cronbach's alpha was examined for all three factors of the 3-factor solution to examine internal consistency reliability. Factor 1 (Q7, 8, 9) and factor 2 (Q1, 2, 3, 6) indicated acceptable reliability ($\alpha>0.85$). Factor 3 (Q4, 5), however, is not found to be reliable ($\alpha=0.525$).

Table 5

Standardized Pattern Coefficients for the Three-Factor Solution of the First EFA

	1	2	3
Q1	-0.92		
Q2	-0.83		
Q3	-0.67	0.33	
Q4			0.63
Q5			0.62
Q6	0.50		
Q7		0.77	
Q8		0.78	
Q9		0.78	

Note. Extraction method was principal axis with an oblique (Promax) rotation. Values below |0.45| are considered poor fit, and values above |0.45| for two factors is considered significant cross-loading.

Table 6

Standardized Pattern Coefficients for the One-Factor Solution of the First EFA

	1
Q1	0.785
Q2	0.687
Q3	0.835
Q4	**-0.318**
Q5	**-0.355**
Q6	0.586
Q7	-0.743
Q8	-0.729
Q9	-0.713

Note. Extraction method was principal axis. Values below |0.45| are considered poor fit. Values below |0.45| are bolded.

For the one-factor solution (Table 6), unrotated PAF loadings are examined with both positive and negative pattern coefficients identified. Two items display excellent positive loading ($|\lambda|>0.71$) and two items display good positive loading ($|\lambda|>0.55$) (Tabachnick & Fidell, 2013). Three items display excellent negative loading ($|\lambda|>0.71$) and two items display poor factor loadings ($|\lambda|<0.45$) (Tabachnick & Fidell, 2013). The two items that display poor factor loadings were Q4 and Q5. Cronbach's alpha is also conducted for the one-factor solution and found to indicate reliability ($\alpha=0.85$). Due to results from both the one and three factor solutions, Q4 and Q5 are removed from the data and another round of EFA was conducted.

Second EFA

PA, MAP, SMT and EMPKC tests are conducted again for the reduced scale through the EFA.dimensions package in RStudio. The PA test returns both a one and two factor solution (Figure 4). This time the MAP test also identified both one and two factor solutions. The SMT test identifies a two-factor solution and the EMPKC test returns a one factor solution. From these results, both two and one factor solutions will be tested.

The two-factor solution is rotated using promax rotation and unrotated loadings are examined for the one-factor solution. Pattern coefficients can be found in Table 7 for the rotated two-factor solution and Table 8 for the unrotated one-factor solution. Within the two-factor solution, one factor (Factor 1) emerged with two items displayed excellent factor loadings ($|\lambda|>0.71$), one item displayed good factor loading ($|\lambda|>0.55$) and one item displaying fair factor loading ($|\lambda|>0.71$) (Tabachnick & Fidell, 2013). A second factor (Factor 2) emerged with all three items, displaying excellent factor loadings ($|\lambda|>0.71$) (Tabachnick & Fidell, 2013). There was no significant cross-loading between items, with all cross-loading values below the cut-off value ($|\lambda|<0.45$) (Hair 2006). Cronbach's alpha was once again examined for both subscales of the two-factor solution and found it indicate internal consistency reliability for both the first ($\alpha=0.86$) and second ($\alpha=0.85$) factor.

For the new one-factor solution (Table 8), unrotated PAF loadings were examined, two items displaying excellent positive loading ($|\lambda|>0.71$), two items displaying good positive loading ($|\lambda|>0.55$), two items displaying excellent negative loading ($|\lambda|>0.71$) and one item displaying poor factor loadings ($|\lambda|<0.45$). Cronbach's alpha was also examined for the one-factor solution and found to indicate reliability ($\alpha=0.89$).

Table 7

Standardized Pattern Coefficients for the Three-Factor Solution of the Second EFA

	1	2
Q1	-0.92	
Q2	-0.87	
Q3	-0.64	
Q6	0.48	
Q7		0.82
Q8		0.80
Q9		0.83

Note. Extraction method was principal axis with an oblique (Promax) rotation. Values below |0.45| are considered poor fit, and values above |0.45| for two factors is considered significant cross-loading.

Table 8

Standardized Pattern Coefficients for the One-Factor Solution of the Second EFA

	1
Q1	-0.80
Q2	-0.69
Q3	-0.86
Q6	0.58
Q7	0.73
Q8	0.72
Q9	0.69

Note. Extraction method was principal axis. Values below |0.45| are considered poor fit, and values above |0.45| for two factors is considered significant cross-loading.

Based on theoretical understanding of subscales and items, the two-factor solution was selected. Here enjoyment and anxiety towards science, both previously identified components of the affective domain of attitude (van Aalderen-Smeets, 2012), are identified as the two factors. The two factors are *Science Anxiety* (Factor 1) with items Q1, Q2, Q3 and Q6 and *Enjoyment of Science* (Factor 2) with items Q7, Q8, and Q9. The *Enjoyment of Science factor* was changed from the *Value and Enjoyment of Science* factor found by Tai et al. (2022) as items indicating value of science (Q4, 5) were removed from the subscale. This new scale with factors of *Enjoyment of Science* and *Science Anxiety*, will be referred to as the modified mATSI:2. The distribution of question responses for all seven items of the newly identified factors can be found in Table 9. The original factors found by Tai et al. (2022) can be found in Table 1.

Modified mATSI:2 Results

Prior to conducing inferential or exploratory analysis, results from the modified mATSI:2 instruments are examined (Table 10; Figure 5). Students provided neutral responses to items Q1 (Mdn=3,IQR=2-4) and Q3 (Mdn=3,IQR=2-4) of the *Science Anxiety* factor and items Q7 (Mdn=3,IQR=2-4), Q8 (Mdn=3,IQR=2-4) and Q9 (Mdn=3,IQR=2-4) of the *Enjoyment of Science* factor. Students disagreed with items Q2 (Mdn=2,IQR=1-3) and Q6 (Mdn=2,IQR=2-3) of the *Science Anxiety* factor, indicating low science anxiety.

Table 9

Distribution of Survey Items Among Key Factors Following EFA

Item Number	Question
	Enjoyment of Science Factor
Q7	Science is something I enjoy very much
Q8	I like the challenge of science assignments
Q9	I have a real desire to learn science
	Science Anxiety Factor
Q1	It makes me nervous to even think about science
Q2	I feel tense/nervous when someone talks to me about science
Q3	It scared me to have to take a science class
Q6	No matter how hard I try, I cannot understand science

Note. Survey items distributed among *Enjoyment of Science* and *Science Anxiety* factors following two rounds of EFA.

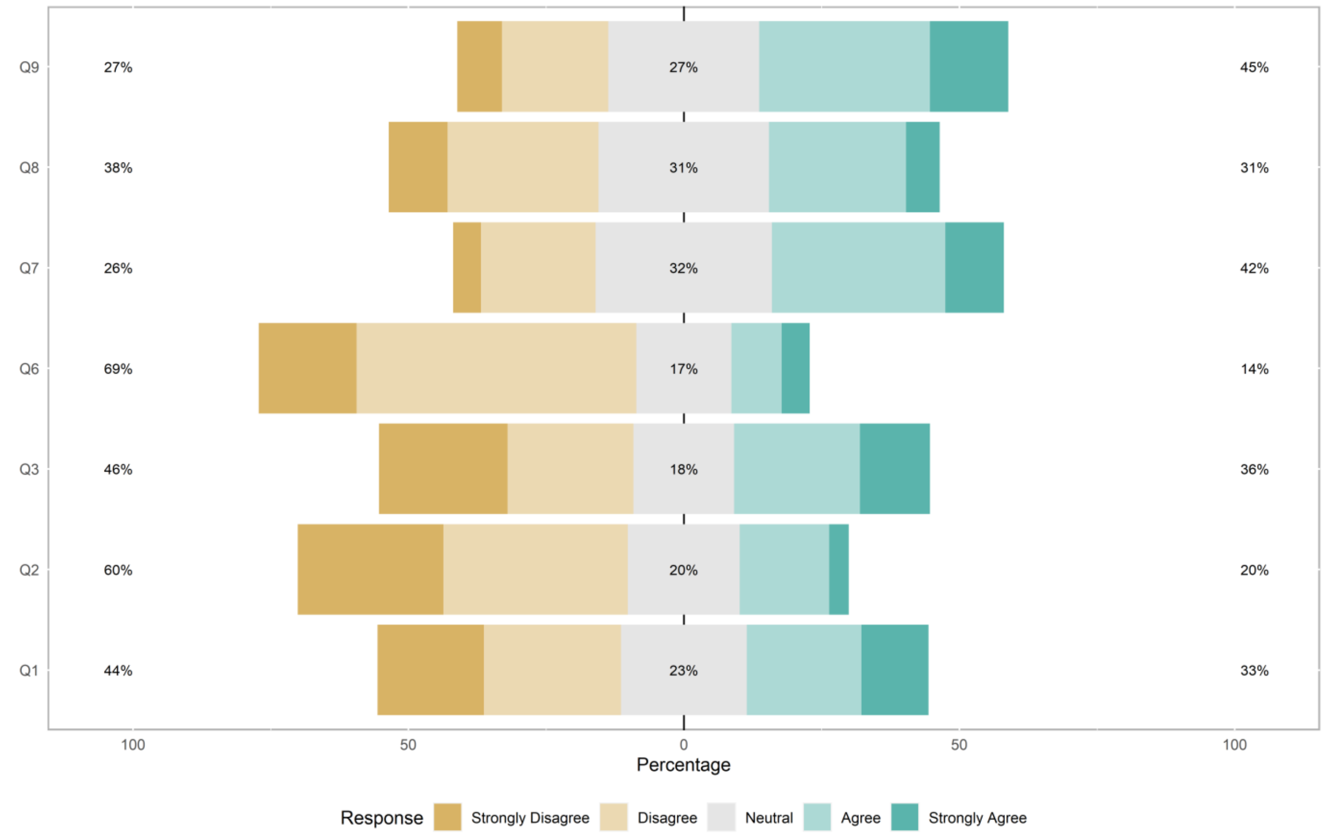
Table 10

Median and Interquartile Range for Modified mATSI:2 Items

Questionnaire Item	Median	IQR
(Q1) It makes me nervous to even think about science	3	2-4
(Q2) I feel tense/nervous when someone talks to me about science	2	1-3
(Q3) It scared me to have to take a science class	3	2-4
(Q6) No matter how hard I try, I cannot understand science	2	2-3
(Q7) Science is something which I enjoy very much	3	2-4
(Q8) I like the challenge of science assignments	3	2-4
(Q9) I have a real desire to learn science	3	2-4

Figure 5

Overall Responses to Modified mATSI:2 Science Attitude Items



Note. Distributions of mATSI:2 responses are shown for the entire analyzed sample.

5.4 Mann-Whitney U Test Findings

Following EFA results, students' science attitudes are examined using the seven items on the two newly identified factors. Demographic responses with unidentified responses or with less than 5 responses are excluded from testing. Two items were excluded when conducting Mann-Whitney U tests examining academic year and science attitudes. Eleven responses were excluded when conducting Mann-Whitney U tests examining gender and science attitudes. First, Shapiro-Wilk tests are examined for all modified mATSI:2 items to determine if univariate normality exists in the data (Table 3). As all questions are found to not follow a normal distribution ($p<0.05$), a non-parametric test must be used to analyze the relationship between science attitudes (Modified mATSI:2 results) and demographic information. Hence the Mann-Whitney U test is used to examine the relationship between science attitudes and demographic information. The Mann-Whitney U test is conducted using the stats package in RStudio, and the median is used to summarize the relationship between science attitudes (Modified mATSI:2 results) and demographic information.

Faculty

Mann-Whitney U tests are conducted to examine differences between demographic information and science attitude ($n=197$) (Table 11). First, differences between student faculty and the factors *Science Anxiety* and *Enjoyment of Science* of science attitudes identified in this study are examined.

Table 11

Mann-Whitney U Test Results Comparing Modified mATSI:2 Responses and Faculty Membership

Factor	Question	Faculty	Mdn	W	z-score	Effect Size	Sig
Science Anxiety Factor	Q1	Sci	2	1653	-6.750276	0.4809373	$1.476e^{-11}$ ***
		NonSci	3				
	Q2	Sci	2	2079	-5.6030173	0.4011332	$1.8e^{-08}$ ***
		NonSci	3				
	Q3	Sci	1	1078	-8.353235	0.5951433	$2.2e^{-16}$ ***
		NonSci	4				
	Q6	Sci	2	2539.5	-4.510555	0.3213637	$6.466e^{-06}$ ***
		NonSci	2				
Enjoyment of Science Factor	Q7	Sci	4	7113.5	-8.625729	0.6145577	$2.2e^{-16}$ ***
		NonSci	3				
	Q8	Sci	4	6847	-7.839944	0.5585729	$4.507e^{-15}$ ***
		NonSci	2				
	Q9	Sci	4	7154	-8.678144	0.6182921	$0.2e^{-16}$ ***
		NonSci	3				

Note. n=197, Mdn=Median, Sci=science, NonSci=nonscience

*p < .05, **p < .01, ***p < .001

Science Anxiety Factor. The results of this analysis determine that, for Q1 ($p<0.001$), Q2 ($p<0.001$), Q3 ($p<0.001$) and Q6 ($p<0.001$), students in the science faculty express significantly less science anxiety compared to nonscience students (Table 11).

For Q1 (*It makes me nervous to even think about science*), science faculties display lower science anxiety (Mdn=2, IQR=1-2) compared to nonscience faculties (Mdn=3, IQR=2-4). A Mann-Whitney-U test displays that this is a statistically significant difference ($W=1653$, $p<0.001$, $r=0.48$).

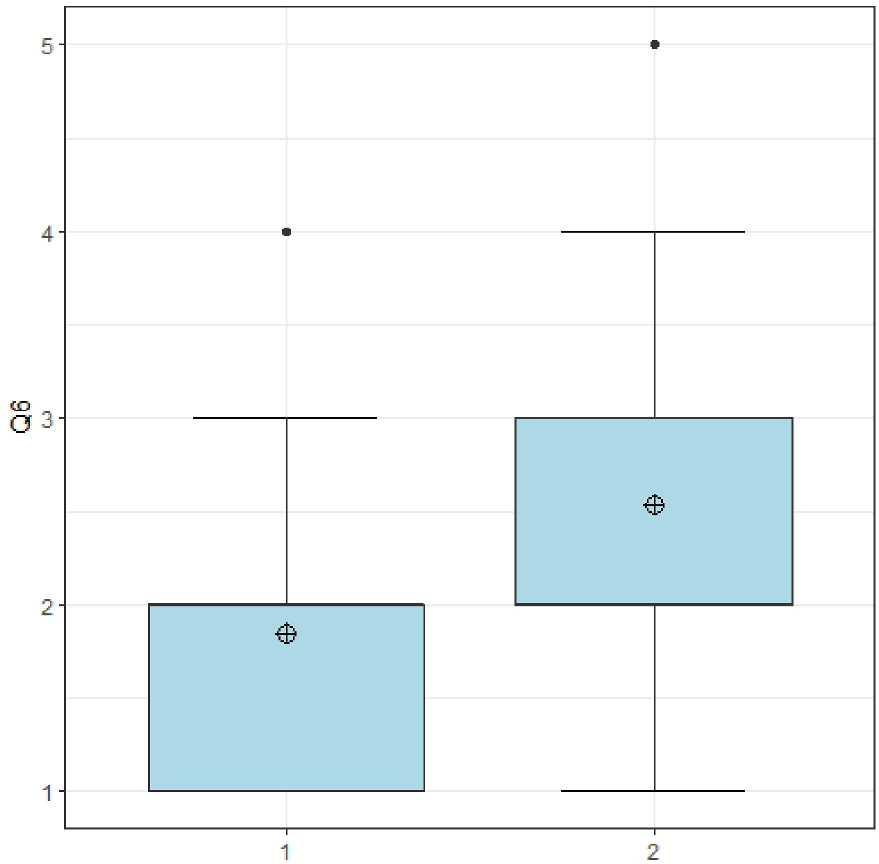
For Q2 (*I feel tense/nervous when someone talks to me about science*), science faculties display lower science anxiety (Mdn=2, IQR=1-2) compared to nonscience faculties (Mdn=3, IQR=2-4). A Mann-Whitney-U test displays that this is a statistically significant difference ($W=2079$, $p<0.001$, $r=0.40$).

For Q3 (*It scared me to have to take a science class*), science faculties display lower science anxiety (Mdn=1, IQR=1-2) compared to nonscience faculties (Mdn=4, IQR=2-4). A Mann-Whitney-U test displays that this is a statistically significant difference ($W=1078$, $p<0.001$, $r=0.60$).

For Q6 (*No matter how hard I try, I cannot understand science*), science faculties display similar science anxiety (Mdn=2, IQR=1-2) compared to nonscience faculties (Mdn=2, IQR=2-3). However, there is still a statistically significant difference between science and nonscience faculties ($W=2539.5$, $p<0.001$, $r=0.32$), which can be seen in Figure 6.

Figure 6

Box Plot of Questions 6 Responses Comparing Science and Nonscience Faculties



Note. The median value is respresented by a bolded line and the mean is represented by the ⊕ symbol. First and third quartiles are represented by the box ends. Whiskers reach out of Q1-1.5*IQR and Q3+1.5*IQR. Potential outliers are represented by dots beyond the whiskers. Science=1, nonscience=2.

Enjoyment of Science Factor. These items are significantly higher in students from a science faculty compared to nonscience faculties on Q7(p<0.001), Q8 (p<0.001) and Q9 (p<0.001).

For Q7 (*Science is something I enjoy very much*), science faculties display higher enjoyment of science (Mdn=4, IQR=4-5) compared to nonscience faculties (Mdn=3, IQR=2-3). A Mann-Whitney-U test displays that this is a statistically significant difference (W=7113.5, p<0.001, r=0.61).

For Q8 (*I like the challenge of science assignments*), science faculties display higher enjoyment of science (Mdn=4, IQR=3-4) compared to nonscience faculties (Mdn=2, IQR=2-3). A Mann-Whitney-U test displays that this is a statistically significant difference (W=6847.5, p<0.001, r=0.56).

For Q9 (*I have a real desire to learn science*), science faculties display higher enjoyment of science (Mdn=4, IQR=4-5) compared to nonscience faculties (Mdn=3, IQR=2-4). A Mann-Whitney-U test displays that this is a statistically significant difference (W=7154, p<0.001, r=0.62).

Academic Year

The differences between science attitudes and academic year are also examined (n-195) (Table 12). Only Q6 (*No matter how hard I try, I cannot understand science),* of the *Science Anxiety* factor displayed a significant difference between academic years when comparing science attitudes (W=4193, p<0.01, r=0.19). On Q6, similar levels of anxiety are displayed by first-year students (Mdn=2, IQR=2-3) compared to upper-year students (Mdn=2, IQR=1-2), however there is still a significant difference with first-year students displaying more science anxiety than upper-year students (Figure 7).

No significant difference is found between students in their first year of university or upper-year students on science attitudes for any other items (p>0.05). However, first-year students display neutral science anxiety on item Q1 (Mdn=3, IQR=2-4), and high science anxiety on items Q2 (Mdn=4, IQR=2-3) and Q3 (Mdn=Q5, IQR=2-4). This is also found in upper-year students, with neutral science anxiety on item Q1 (Mdn=3, IQR=1-4), and high science anxiety on items Q2 (Mdn=4, IQR=1-4) and Q3 (Mdn=Q5, IQR=1-4). Students exhibit neutral enjoyment of science regardless of academic year. Neutral responses are recorded for both males and females on Q7 (Mdn=3, IQR=2-4), Q8 (Mdn=3, IQR=2-4) and Q9 (Mdn=3, IQR=2-4).

Gender

Finally, student gender and science attitudes are examined (n=186) (Table 13). Males and females are found to be significantly different on two *Science Anxiety* factor items- Q1 (*It makes me nervous to even think about science)* (W=2948.5, p<0.05, r=0.16), and Q3 (*It scared me to have to take a science class)* (W=2943.5, p<0.05, r=0.16). On Q1, males (Mdn=2, IQR=2-3) express positive science attitudes, while females express neutral science attitudes (Mdn=3, IQR=2-4). This is displayed on Q3 as well, with males (Mdn=2, IQR=2-3) expressing positive science atttiudes and females displaying neutral science attitudes (Mdn=3, IQR=2-4).

Table 12

Mann-Whitney U Test Results Comparing Modified mATSI:2 Responses and Academic Year

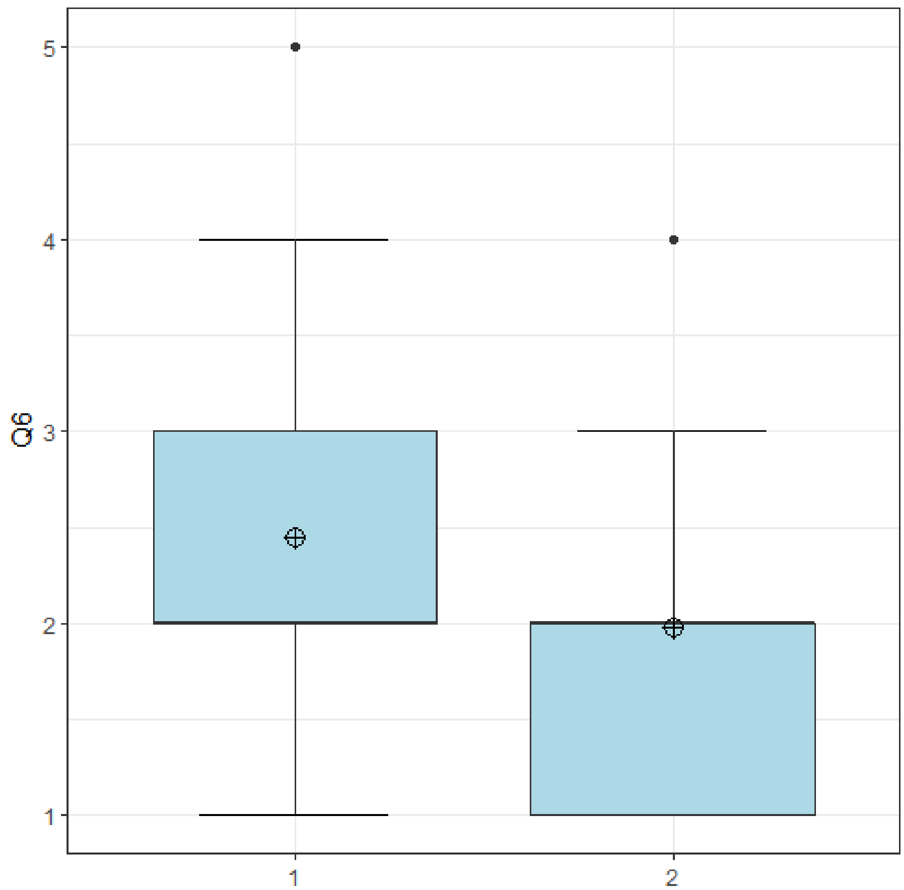
Factor	Question	Year	Mdn	W	z-score	Effect Size	Sig
Science Anxiety Factor	Q1	FY	3	3614	-0.7351403	0.05264449	0.4623
		UY	3				
	Q2	FY	4	3666.5	-0.9078112	0.06500971	0.364
		UY	4				
	Q3	FY	5	3497.5	-0.3758737	0.02691687	0.707
		UY	5				
	Q6	FY	2	4193	-2.658555	0.1903831	0.007848**
		UY	2				
Enjoyment of Science Factor	Q7	FY	3	3043.5	-1.035661	0.07416524	0.3004
		UY	3				
	Q8	FY	3	3080.5	-0.9167094	0.06564692	0.3593
		UY	3				
	Q9	FY	3	3126.5	-0.7702958	0.05516203	0.4411
		UY	3				

Note. n=195, Mdn=Median, FY=First-Year, UY=Upper-Year

*p < .05, **p < .01, ***p < .001

Figure 7

Box Plot of Question 6 Responses Comparing First-Year and Upper-Year Students



Note. The median value is respresented by a bolded line and the mean is represented by the ⨁ symbol. First and third quartiles are represented by the box ends. Whiskers reach out of Q1-1.5*IQR and Q3+1.5*IQR. Potential outliers are represented by dots beyond the whiskers. First-Year=1, Upper-Year=2.

Table 13

Mann-Whitney U Test Results Comparing Modified mATSI:2 Responses and Gender

Factor	Question	Gender	Median	W	z-score	Effect Size	Sig
Science Anxiety Factor	Q1	Male	2	2948.5	-2.200526	0.1613504	0.02777*
		Female	3				
	Q2	Male	2	3304	-1.138384	0.08347036	0.255
		Female	2				
	Q3	Male	2	2943.5	-2.214427	0.1623696	0.0268*
		Female	3				
	Q6	Male	2	3417	-0.8293643	0.06081194	0.4069
		Female	2				
Enjoyment of Science Factor	Q7	Male	3	3431.5	-0.751402	0.05509547	0.4524
		Female	3				
	Q8	Male	3	3620	-0.1714407	0.01257065	0.8639
		Female	3				
	Q9	Male	3	3257	-1.280192	0.09386821	0.2005
		Female	3				

Note. n=186

*p < .05, **p < .01, ***p < .001

No significant difference in science attitudes is found between male and female students on any other items. Male students display low science anxiety on Q2 (Mdn=2, IQR=1-3) and Q6 (Mdn=2, IQR=2-2) of the *Science Anxiety* factor. Female students display low science anxiety on Q2 (Mdn=2, IQR=1-3) and Q6 (Mdn=2, IQR=2-3) of the *Science Anxiety* factor.

Male students also display neutral enjoyment of science for Q7 (Mdn=3, IQR=3-4), Q8 (Mdn=3, IQR=2-3) and Q9 (Mdn=3, IQR=2-4) of the *Enjoyment of Science* factor. Female students display neutral enjoyment of science for Q7 (Mdn=3, IQR=2-3), Q8 (Mdn=3, IQR=2-4) and Q9 (Mdn=3, IQR=2-4) of the *Enjoyment of Science* factor.

5.5 Cluster Analysis Findings

Cluster analysis is used in this study to identify meaningful clusters of students and characterise the science attitudes of a diverse group of students. Clusters are determined using results from only the modified mATSI:2 survey, which will be compared with demographic distributions for further analysis.

The Hopkins statistic was calculated to determine whether the data was clusterable. The Hopkins statistic was calculated with the Hopkins package in RStudio 100 times using a sample of 19.8% of the analyzed data, resulting in an average Hopkins statistic of 0.8462 (IQR=0.7884-0.9097). Results can be found in Table 14. Values of 0.7-1 indicate clustered data within the RStudio Hopkins package, so our results indicate a high clustering tendency (Wright, 2022).

Table 14

Descriptive Statistics of 100 Hopkins Statistic Tests

Min	1st Q	Median	Mean	3rd Q	Max
0.5205	0.7884	0.8590	0.8462	0.9097	0.9720

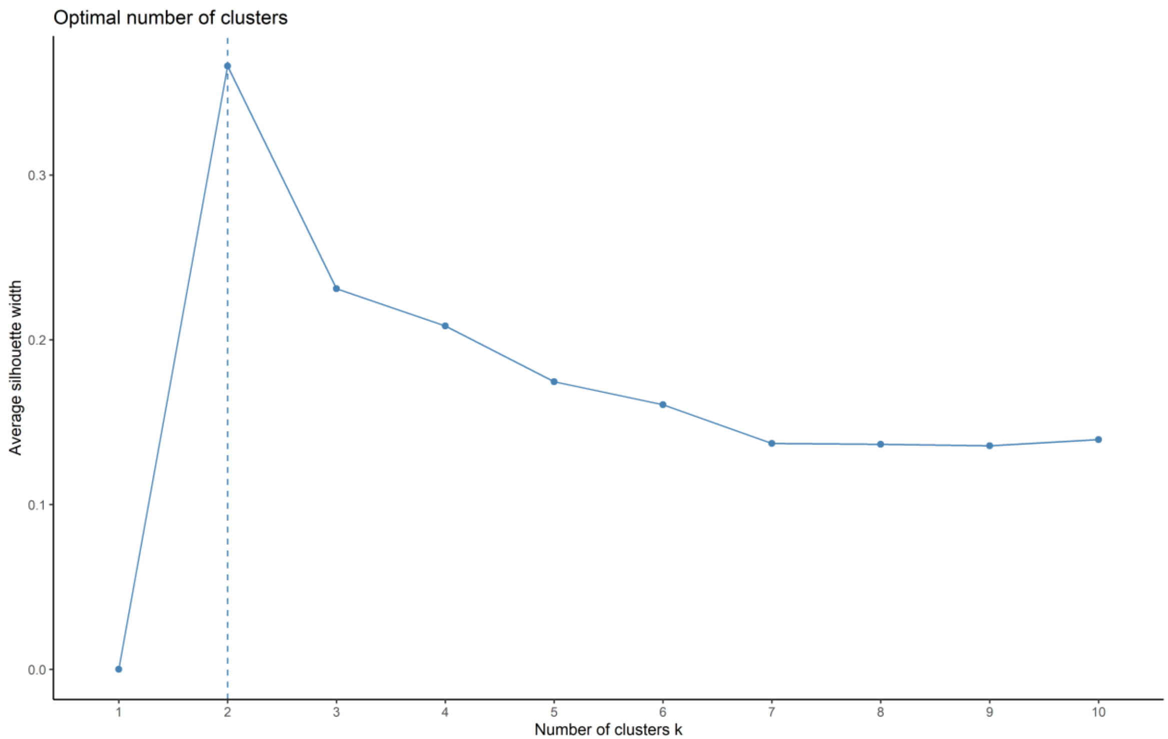
Note. Mean and median values >0.7 indicate clustered data.

Once data was found to be clusterable, the optimal number of clusters was determined by examining the silhouette statistic, the gap statistic and using the elbow method for within sum of square for mATSI:2 responses. All three tests were administered using the Factoextra package within RStudio. Using the silhouette statistic, 2 clusters were determined to be the optimal solution (Figure 8) with an average silhouette width of 0.44. Results for the average silhouette width can be found in Figure 9. It is worth noting that a subset of the data (n=10) was identified with negative silhouette widths ranging from -0.041386360 to -0.111079955. Negative widths on silhouette scores do suggest these objects may not be cohesive with their assigned cluster, could overlap with another cluster or could be the result of noise (Kaufman & Rousseeuw, 1990).

The optimal number of clusters determined via the gap statistic was two, where the 1-standard-error method criteria was met (Figure 10) (Tibshirani, 2001). In addition, the elbow method was utilized by comparing the total within sum of squares between different cluster numbers. Here an optimal two cluster solution was determined (Figure 11). Comparing all three tests, a two-cluster solution was found to be optimal.

Figure 8

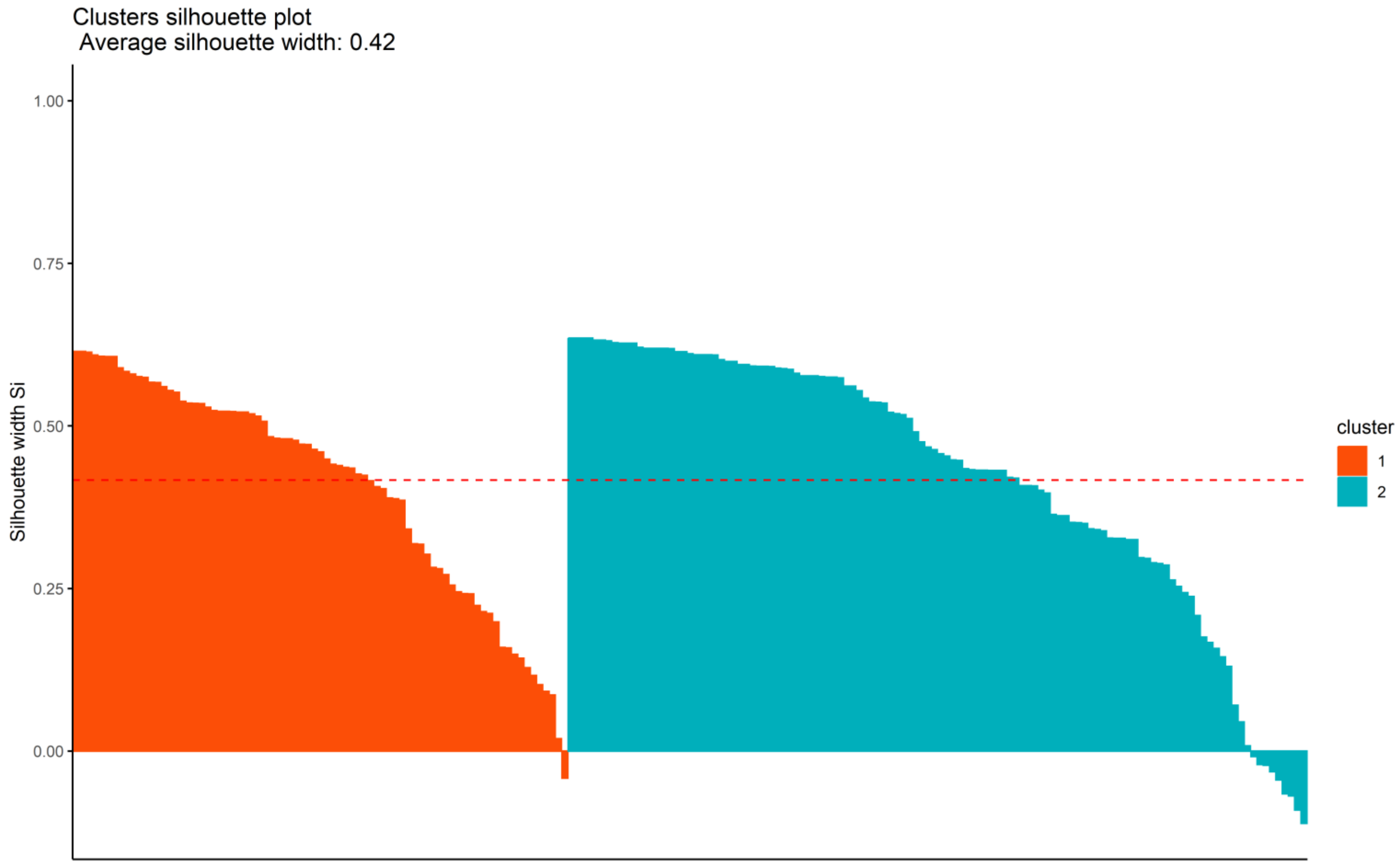
Silhouette Statistic based on Average Silhouette Width for Determining Cluster Membership



Note. Visualization of the optimal number of clusters using the average silhouete width of clusters. Optimal number of clusters represented by the dotted line.

Figure 9

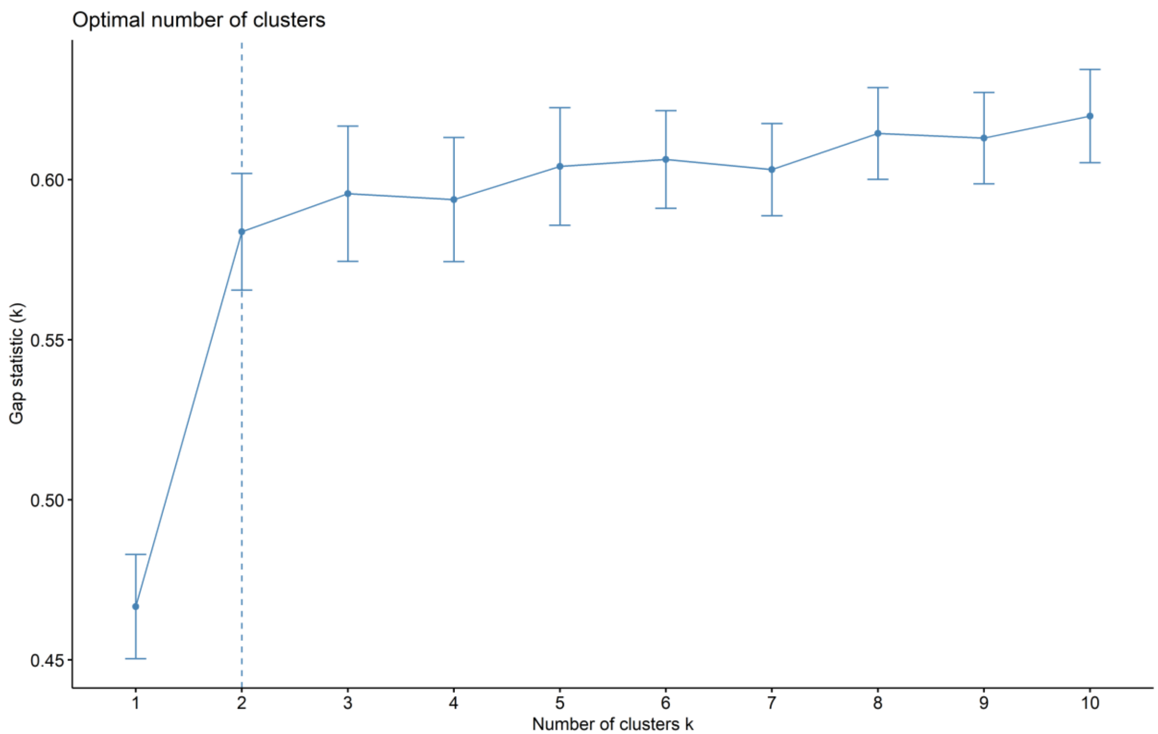
Silhouette Plot Displaying Differences in Silhouette Width Between Cluster 1 and 2



Note. Visualization of silhouette information from PAM clustering. Average silhouette width=0.42,

Figure 10

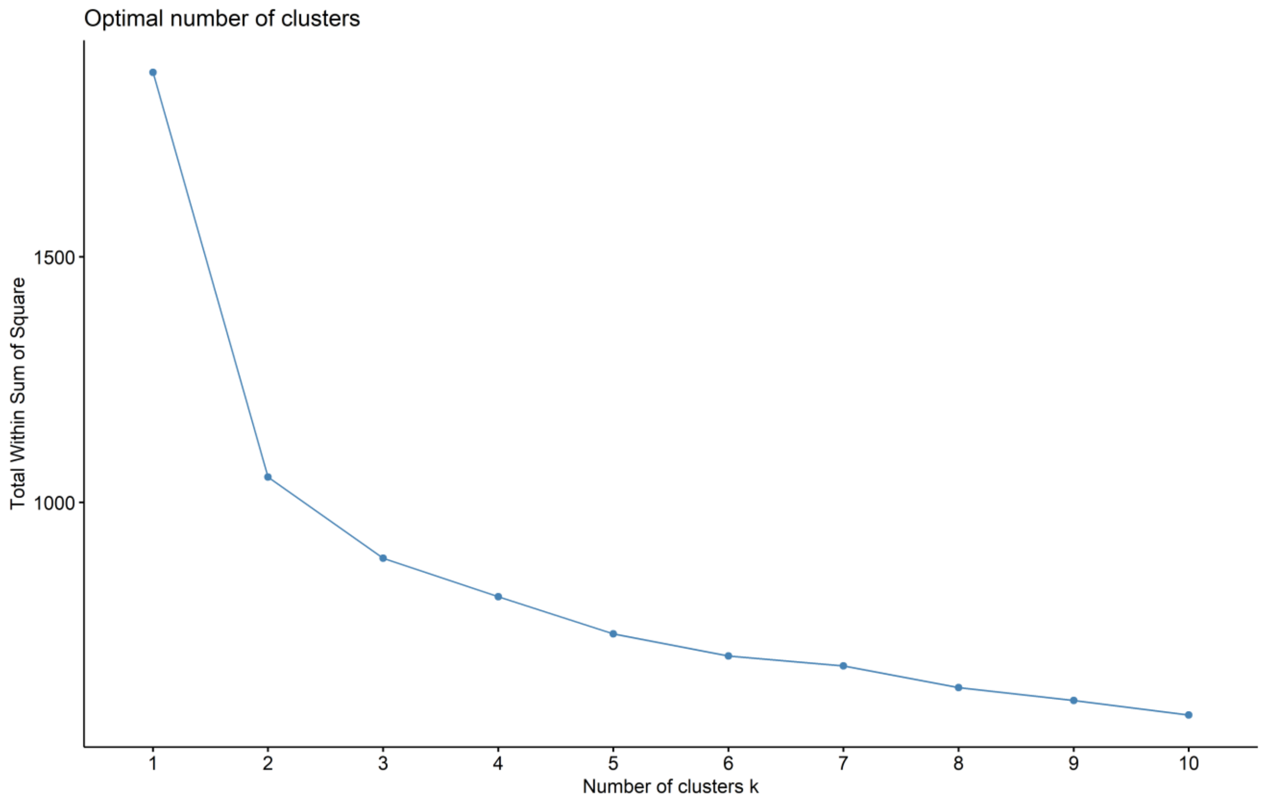
Gap Statistic for Determining Cluster Membership



Note. Visualization of the optimal number of clusters using the gap statistic. Optimal number of clusters represented by the dotted line.

Figure 11

Average Total Within Sum of Square for Determining Cluster Membership



Note. Visualization of the optimal number of clusters using total within sum of square. Optimal number of clusters represented by the "elbow".

With an optimal number of clusters determined, Partitioning Around Medoids (PAM) clustering algorithm was used to create the clusters, using a Manhattan distance technique for clustering (Appendix B). The cluster data package was used to calculate clusters using the PAM clustering algorithm. Two distinct clusters among participants emerged based on responses to the modified mATSI:2 survey, where each cluster was unique on all 7 items. A visualization of cluster items can be found in Figure 12.

The clusters that emerged can be classified as:

Cluster 1 – Low enjoyment, high anxiety regarding science

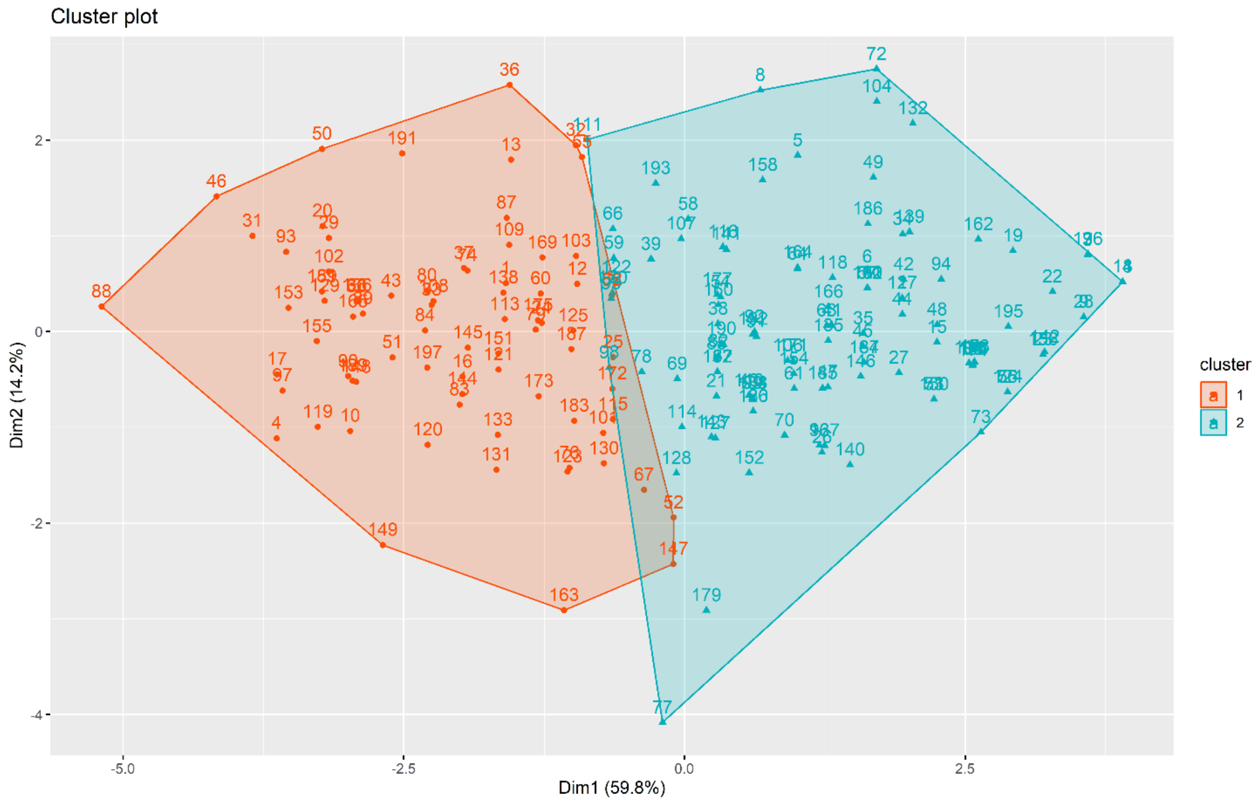
The first cluster consists of 40.1% of participants (n=79). Distribution of answers to modified mATSI:2 items can be found in Figure 13, with median values reported in Table 15. These participants expressed low enjoyment of science for majority of responses on Q7 (Mdn=2, IQR=2-3), Q8 (Mdn=2, IQR=2-2) and Q9 (Mdn=2, IQR=2-3), all questions examining enjoyment of science. They also expressed high science anxiety in majority of respondents for Q1 (Mdn=4, IQR=3.5-5) and Q3 (Mdn=4, IQR=4-5). For Q2 (Mdn=3, IQR=2-4) and Q6 (Mdn=3, IQR=2-3.5), which also examined science anxiety, there was a mixed response with many answers agreeing with, disagreeing with or remaining neutral to the questions.

Cluster 2 – High enjoyment, low anxiety regarding science

The second cluster consists of 60.1% of participants (n=118). Distribution of answers to modified mATSI:2 items can be found in Figure 14, with median values reported in Table 15. These participants expressed high enjoyment of science for majority of responses on Q7 (Mdn=4, IQR=3-4), Q8 (Mdn=3.5, IQR=3-4) and Q9 (Mdn=4, IQR=3-4), two of three questions examining enjoyment of science. They also expressed low science anxiety in majority of respondents for Q1 (Mdn=2, IQR=1-3), Q2 (Mdn=2, IQR=1-2), Q3 (Mdn=2, IQR=1-2) and Q6 (Mdn=2, IQR=1-2).

Figure 12

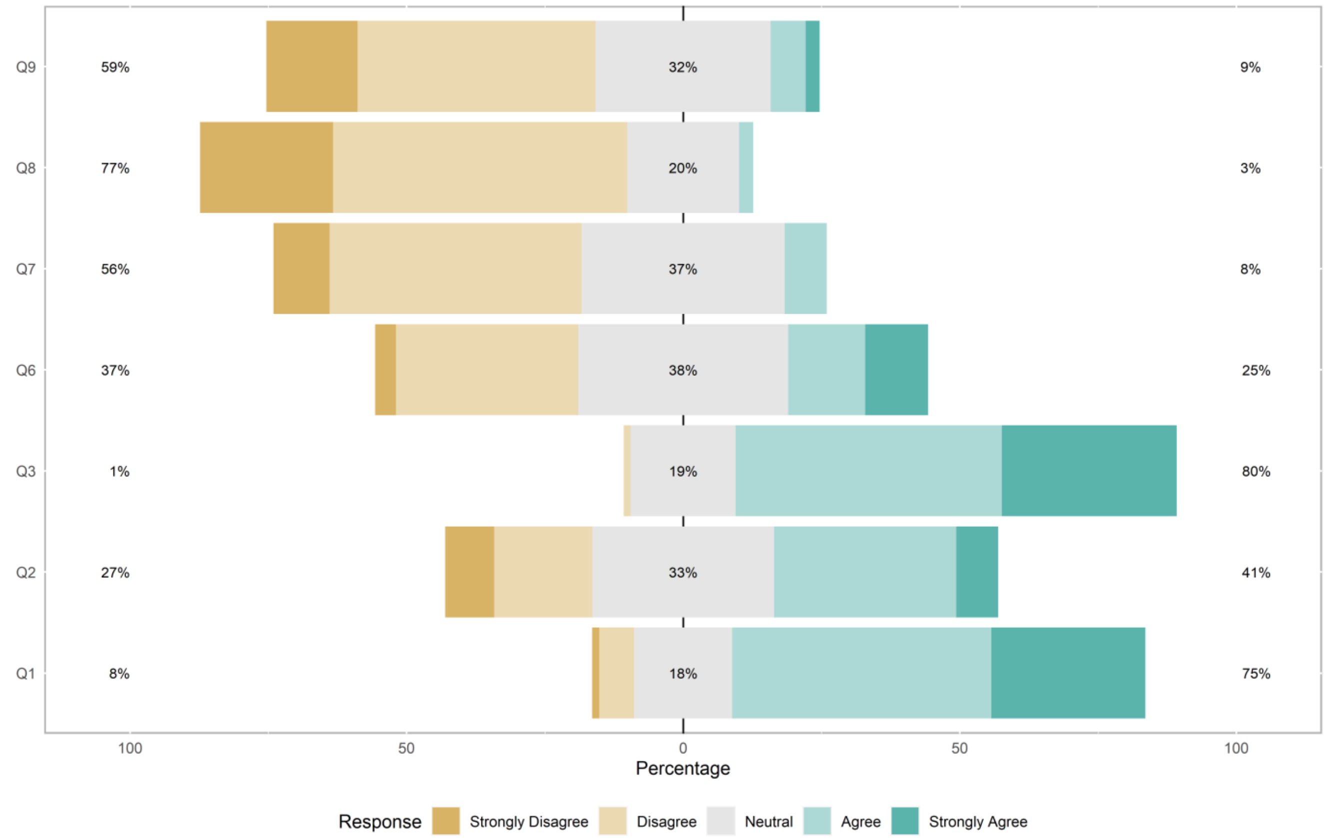
Cluster Visualization Using Principal Component Analysis



Note. Visualization of PAM k-medoids clustering

Figure 13

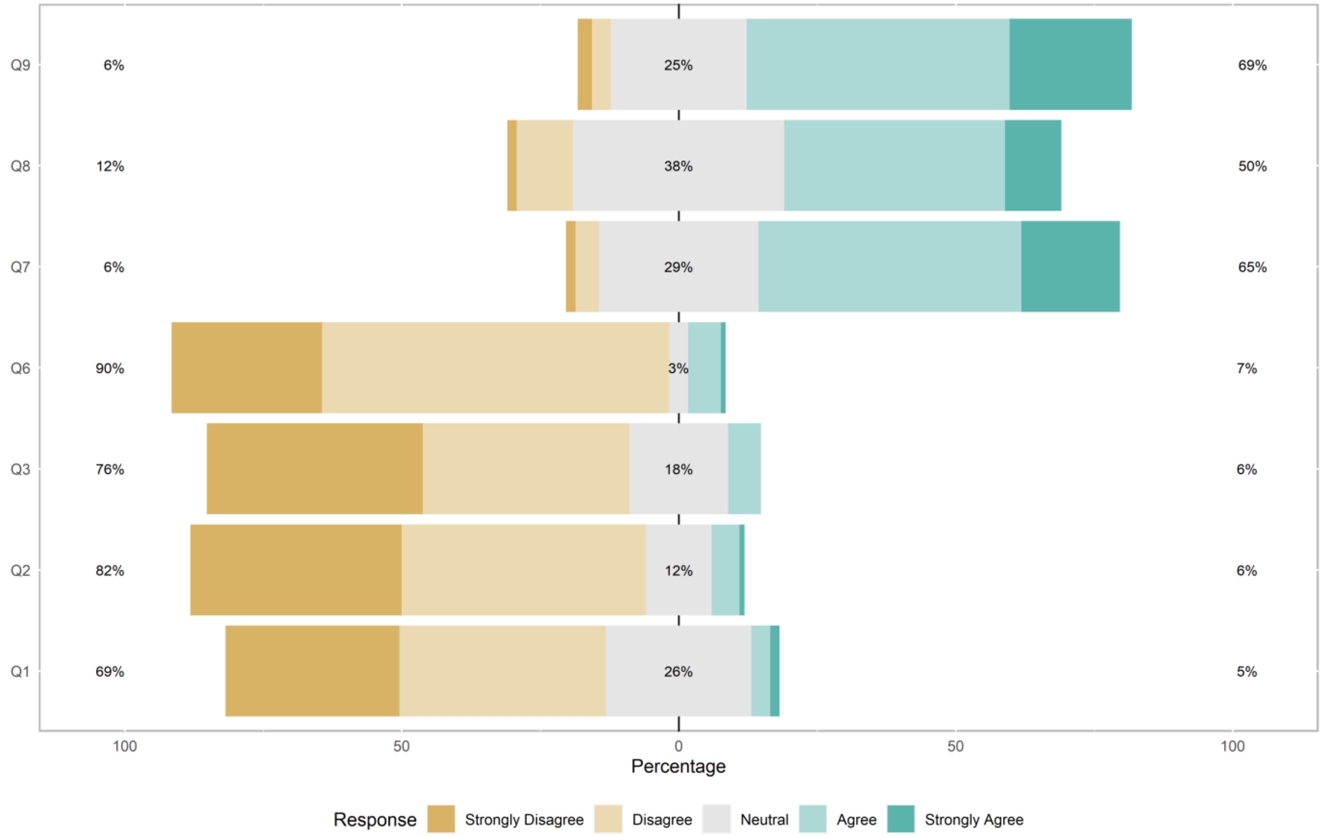
Cluster 1 Responses to the Modified mATSI:2 Survey



Note. Distributions of mATSI:2 responses are shown for the sample of students in cluster 1.

Figure 14

Cluster 2 Responses to the Modified mATSI:2 Survey



Note. Distributions of mATSI:2 responses are shown for the sample of students in cluster 2.

Table 15

Median and Interquartile Range for Modified mATSI:2 Items by Cluster

	Cluster 1		Cluster 2	
Questionnaire Item	Mdn	IQR	Mdns	IQR
(Q1) It makes me nervous to even think about science	4	3-5	2	1-3
(Q2) I feel tense/nervous when someone talks to me about science	3	2-4	2	1-2
(Q3) It scared me to have to take a science class	4	4-5	2	1-2
(Q6) No matter how hard I try, I cannot understand science	3	2-3	2	1-2
(Q7) Science is something which I enjoy very much	2	2-3	4	3-4
(Q8) I like the challenge of science assignments	2	2-2	3.5	3-4
(Q9) I have a real desire to learn science	2	2-3	4	3-4

Note. Mdn=Median, IQR=Interquartile Range

5.6 Chi-Square Test Findings

To further investigation into difference between clusters, differences between demographic distributions of cluster members are assessed. Chi-square tests are conducted using the stats package in RStudio to determine association between faculty membership, gender, and academic year with cluster membership.

First, a chi-square test is conducted to assess whether faculty membership is associated with cluster membership (n=197). Within the total analyzed sample for cluster 1 (n=79) and cluster 2 (n=118), more nonscience (n=138) faculty students are present in the sample compared to science (n=59) faculty students. After performing a chi-squared test, faculty membership is found to be significantly associated with cluster membership ($X^2(1,n=197)=51.722, p<0.001$). Most science faculty students are found to be in cluster 2 (n=58), with a smaller group of students (n=1) in cluster 1 (Table 16). A slight majority of nonscience faculty students are in cluster 1 (n=78), with the remaining students in cluster 2 (n=60) (Table 16).

Next, a chi-squared test is conducted to determine if cluster membership is associated with student gender. Male and female participants are included in this chi-squared test, while unidentified answers (n=10) and genderqueer responses are not included due to low sample size (n=1). After removal of data, the total analysed sample (n=186) for cluster 1 (n=79) and cluster 2 (n=118) consists of more female students (n=129) than male students (n=57).

Table 16

Clusters and Faculty, Frequencies and Percentages

Cluster	Faculty		Total
	Science	Nonscience	
Cluster 1	1	78	79
	1.7%	56.5%	40.1%
Cluster 2	58	60	118
	98.3%	43.5%	59.9%
Total	59	138	197
	100%	100%	100%

Note. $X^2(1, n=197)=51.722$, $p<0.001$

After performing a chi-squared test, gender is found to not be significantly associated with cluster membership ($X^2(1,n=186)=0.93594, p>0.05$). More male (n=37) and female (n=74) students are found in cluster 2, with a smaller sample of male (n=20) and female (n=55) students in cluster 1 (Table 17).

Finally, a chi-squared test is conducted to determine if cluster membership is associated with student academic year. For analysis of academic year, unidentified responses (n-2) are not included in data analysis. After removal of data, the total analysed sample (n=195) for cluster 1 (n=79) and cluster 2 (n=116), consists of more first-year students (n=150) than upper-year students (n=45). Following a chi-squared test, academic year is found to not be significantly associated with cluster membership ($X^2(1,n=195)=0.0063837, p>0.05$). More first-year (n=89) and upper-year (n=27) students are found in cluster 2, with a smaller sample of first-year (n=61) and upper-year (n=18) students in cluster 1 (Table 18).

Table 17

Clusters and Gender, Frequencies and Percentages

Cluster	Gender		Total
	Male	Female	
Cluster 1	20	55	75
	35.1%	42.6%	40.3%
Cluster 2	37	74	111
	64.9%	57.4%	59.7%
Total	57	129	186
	100%	100%	100%

Note. $X^2(1, n=186)=0.93594$, $p>0.05$

Table 18

Clusters and Academic Year, Frequencies and Percentages

Cluster	Academic Year		Total
	First-Year	Upper-Year	
Cluster 1	61	18	79
	40.7%	40.0%	40.5%
Cluster 2	89	27	116
	59.3%	60.0%	59.5%
Total	150	45	195
	100%	100%	100%

Note. $X^2(1, n=195)=0.0063837$, $p>0.05$

5.7 Key Findings

A few notable results were found in this study. First, significantly differences were found for science attitudes based on faculty membership ($p<0.001$), with science faculty students displaying more positive science attitudes than nonscience faulty students (Figure 15). Next, science attitudes between first-year and upper-year students were only significantly different on one item of the *Science Anxiety* factor ($p<0.01$)- Q6 (*No matter how hard I try, I cannot understand science).* Male and female students displayed significant differences on two science anxiety items ($p<0.05$), Q1 (*It makes me nervous to even think about science*), and Q3 (*It scared me to have to take a science class*). Two clusters were identified- cluster 1, which consists of students with low enjoyment and high anxiety regarding science and cluster 2 with students displaying high enjoyment and low anxiety regarding science. Only faculty was found to be significantly different between clusters, with most science faculty students found in cluster 2 (n=58), and a smaller group of students (n=1) in cluster 1. Nonscience faculty students are split between cluster 1 (n=78) and cluster 2 (n=60). In the next chapter, key findings are discussed with reference to literature and conceptual frameworks.

Figure 15

Key Mann-Whitney U Test Results Comparing Modified mATSI:2 Responses and Faculty Membership

Science Anxiety Factor	
Q1	It makes me nervous to even think about science
Q2	I feel tense/nervous when someone talks to me about science
Q3	It scared me to have to take a science class
Q6	No matter how hard I try, I cannot understand science
Enjoyment of Science Factor	
Q7	Science is something I enjoy very much
Q8	I like the challenge of science assignments
Q9	I have a real desire to learn science

Mann-Whitney U Test Results Comparing Modified mATSI:2 Responses and Faculty Membership

Factor	Question	Faculty	Median
Science Anxiety Factor	Q1***	Sci	2
		NonSci	3
	Q2***	Sci	2
		NonSci	3
	Q3***	Sci	1
		NonSci	4
	Q6***	Sci	2
		NonSci	2
Enjoyment of Science Factor	Q7***	Sci	4
		NonSci	3
	Q8***	Sci	4
		NonSci	2
	Q9***	Sci	4
		NonSci	3

Note. n=197, Sci=science, NonSci=nonscience, Green=Positive ATS, Red=Negative ATS
*p < .05, **p < .01, ***p < .001

Chapter VI: Discussion

In this chapter, findings related to students' science attitudes within an introductory university environmental science course are examined and discussed with reference to the research questions, conceptual frameworks and previous literature. Further, the relationship between science attitudes and demographic information of gender, faculty and academic year are examined. Identified cluster differences are assessed to determine how they differ based on gender, faculty, or academic year. The impacts of these results and their consequences for university educators are also discussed.

The following research questions are discussed this chapter:

1. What are students' science attitudes in an introductory environmental science course?
    a. How do components of science attitude differ based on gender, faculty and/or year of degree program?
2. Can clusters be identified based on components of students' science attitudes within an introductory environmental science course?
    a. How do clusters differ based on gender, faculty and/or year of degree program?

There are a few key findings within this research. First, the data suggests that students enrolled in a science faculty display significantly more positive attitudes towards science than students enrolled in nonscience faculties. This supports the theory that faculty is a predictor of science attitudes (Robinson, 2012). The analysis also identifies that first-year students only display significantly more negative science attitudes on a single item, Q6 (*No matter how hard I try, I cannot understand science)* of the *Science Anxiety* factor compared to upper-year students. Additionally, males display more positive scientific attitudes on two items, Q1 (*It makes me nervous to even think about science*) and Q3 (*It scared me to have to take a science class*) of the *Science Anxiety* factor compared to females.

Meaningful clusters do emerge from the data with cluster 1 consisting of students with a low enjoyment and high anxiety towards science, and cluster 2 consisting of students with a high enjoyment and low anxiety towards science. The only significant demographic difference between clusters was faculty, with cluster 1 containing significantly more nonscience faculty students (n=78) and less science faculty students (n=1) than cluster 2, which contained less nonscience faculty students (n=60) and more science faculty students (n=58). There were no significance differences between clusters based on gender or academic year. This result is different than previous research (Ma, 2022), which found gender to differ between student profiles.

6.1 Dropped Items - Value of Science

It is worth noting, prior to discussion of analyzed survey items, that two items from the *Value and Enjoyment of Science* factor in the original mATSI:2 survey were dropped in this study. These items are Q4 (*science is useful in helping to solve the problems of everyday life)* and Q5 (*science is helpful in understanding today's world*), both of which are the value of science items in the aforementioned factor. While they did not load onto the new *Enjoyment of Science* factor examined in this study, an understanding of value of science items can still be important to predict future behaviour. Value has a significant association with attitude (Ajzen & Fishbein, 1969), and both value and attitudes can also be used to predict behaviour (Ajzen, 2012). Inclusion of additional value measures can even influence profile identification results. For example, Ma (2022) utilized multiple TIMSS scales to assess students attitudes towards science, including an eight-item TIMSS Student Value Science scale. They identified two negative profiles when examining attitudes towards science: one profile that displayed negative attitudes towards perceived competence in science, and a second profile that displayed negative attitudes towards instrumental value of science. Within this study, as value of science items were not included within any analysis, there is a potential missing factor. Future research should aim to examine the value of science in more depth and compare its impacts on science attitudes in comparison to both enjoyment of science and science anxiety.

6.2 RQ1: What are students' science attitudes in an introductory environmental science course?

Science attitudes are examined through a series of 7 questions split into two factors- the *Enjoyment of Science* factor and the *Science Anxiety* factor (Table 9). As the affective domain of attitude examined within this study may be a predictor of behavioural intention (Ong et al., 2022), and in turn behaviour, the development of positive science attitudes is important. As per the tripartite model of attitudes, however, results from this study only examine one domain of attitude, so results on the impact of attitudes examined in this study focus on the feelings and emotions felt by students (called *attitudes towards science* in this study), rather than the conative or cognitive domains of attitude. Thus, any results presented only present a picture of one aspect of the sample's potential attitudes. Additionally, as behaviours and behavioral intentions are not examined, no definitive behavioural effects can be found from the results of this study.

Within responses from the analysed sample (n=197), students primarily expressed neutral attitudes towards science on all *Enjoyment of Science* factor items, and both Q1 and Q3 of the *Science Anxiety* factor items. Students expressed positive attitudes towards science on Q2 and Q6 of the *Science Anxiety* factor, indicating low science anxiety for these items. The split response for the *Science Anxiety* factor items could be related to the different topics examined by each of the four questions under this factor. A split response in descriptive statistics is displayed also by Ong et al. (2022) using their own self-developed science attitudes questionnaire. They found mean responses for 2 items indicating negative scores and 3 items indicating positive scores in the affective domain of attitude towards chemistry.

These results initially appear to be promising, as science attitudes have previously been found to negatively impact students' intentions to continue with science education. Ong et al. (2022) found the affective domain of attitude, which is examined in my research, to specifically have a significant impact on intention to continue enrolling in chemistry-related courses. Researchers have also found that negative science anxiety has negative consequences on students, including poor performance both on exams and in the classroom (Alvaro, 1978; Mallow 1978; Udo et al., 2004) and science avoidance in the future (Mallow et al., 2010). While not examined within this study, identification of which demographic populations display negative science attitudes is an indicator of who is at risk for reduced academic performance. Results from this study can be used to inform both future research and curriculum changes to identify and meet the needs of these identified populations. This will ensure that students are academically successful in the science classroom.

6.3 RQ1a: How do components of science attitude differ based on gender, faculty and/or year of degree program?

Responses to the modified mATSI:2 instrument indicated differences in science attitudes between students of different demographics. This included significant differences on items for students' genders, faculties, and level of education.

Faculty

Statistically significant differences in science attitudes were found between science and nonscience faculty students on all seven items ($p<0.001$) of the modified mATSI:2 instrument (Table 11).

Science faculty students display low science anxiety on all *Science Anxiety* factor items, and high enjoyment of science on all *Enjoyment of Science* factor items, indicating positive attitudes towards science. This is contrasted, however, by responses from nonscience faculty students, which display more negative attitudes towards science on all modified mATSI:2 items. This is consistent with previous research conducted by Robinson (2012), who found nonscience major students have more negative views towards science, scientific inquiry and the enjoyment of science lessons compared to science major students. It is also consistent with research by Megreya (2021) who found nonscience students to display more science anxiety than science students in senior secondary and university courses, and Udo et al. (2004) who found nonscience faculty students to exhibit significant levels of science anxiety. This tells us that nonscience faculty students require supports within the classroom to ensure they develop positive attitudes towards science.

While nonscience faculty students in this study do display more negative attitudes towards science, the results of modified mATSI:2 items vary. Neutral responses are found on items Q1 and Q2 of the *Science Anxiety* factor, and on items Q7 and Q9 of the *Enjoyment of Science* factor. Negative responses are found on item Q3 of the *Science Anxiety* factor, and Q8 of the *Enjoyment of Science* factor, indicating high science anxiety on these items. Both Q3 (*I like the challenge of science assignments*) and Q8 (*It scared me to have to take a science class*) refer to the science classroom, suggesting that students from nonscience faculties display negative science attitudes towards the science classroom. Responses to Q6 (*No matter how hard I try, I cannot understand science*) of the *Science Anxiety* factor, however, reported low science anxiety. This indicates that while many nonscience students reported more negative science attitudes on Q6 compared to science faculty students, they still do believe they can understand science. Along with the results from Q3 and Q8, this suggests it is not the science content that students display negative attitudes towards, but rather another aspect of the science classroom. Previous research (Kazempour & Amirshokoohi, 2013; Walczak & Walczak, 2009) has found learner-centered approaches to teaching science to have positive effects on attitudes towards science. Future research should examine if increased use of similar learner-centered approaches would improve students' attitudes towards the science classroom in introductory science courses.

Academic Year

In this study a significant difference between first-year (Mdn=2, IQR=2-3) and upper-year (Mdn=2, IQR=1-2) students is only found on one item ($p<0.01$), Q6 (*No matter how hard I try, I cannot understand science*), of the *Science Anxiety* factor. Results display that both first year and upper-year students feel they can understand science topics, but upper year students feel they can understand science significantly more.

No significant differences are found on any other items measuring science attitudes between students in their first year or upper years of university. This indicates that on most *Science Anxiety* factor items, and all *Enjoyment of Science* factor items, first-year and upper-year students in this study do not display any significant difference from one another.

The results of this study do not support the continuation of a trend of attitudes towards science becoming more negative as students progress through schooling, which has been noted as students transition from elementary to junior high school (Susilawati et al., 2022). They also do not support a trend of increasing attitudes towards science as student progress through schooling, which has been found in secondary schooling and between university and adult students. Summers (2021) found grade 11 students displaying more positive attitudes towards science than grade 9 students. As well, an increasing trend in positive science attitudes from nonscience university students to adult learners is noted by Impey et al. (2021). Results from this study suggest that attitudes towards science, for students enrolled in introductory environmental science courses, the same for most items regardless of academic year.

Upon further examination of the items that do not display a significant difference between academic years, both first year and upper-year students display neutral science anxiety on item Q1, and high science anxiety on items Q2 and Q3. Students also exhibit neutral enjoyment of science on all *Enjoyment of Science* factor items regardless of academic year.

Current research based in the TPB indicates that science attitudes and intention to enroll in science courses are significantly associated with each other (Summers, 2021). Additionally, intention is a significant predictor of future science course enrollment (Summers, 2021). Within the context of this study, this means that both first-year and upper-year students may display the same intentions to enroll in future science courses. However, as the results from this study indicate either neutral or negative responses on all items except for item Q6 (*No matter how hard I try, I cannot understand science*), intention to enroll in future science courses may not be high for both first-year and upper-year students. Future research would be needed to better characterize this issue, and to examine whether there is a difference in both intentions to enroll and actual enrollment for first-year and upper-year students taking introductory science courses.

Gender

Gender is well-characterized to be associated with science anxiety in the literature, with females often cited as displaying lower attitudes towards science compared to makes (Ma, 2022; Osborne et al., 2003; Wan & Lee, 2017). This trend, however, has been challenged. Robinson (2012) noted positive attitudes for both males and females towards science in community college students and Susilawati et al. (2022) found females to have more positive attitudes toward science than males in middle school students. My research extends on this knowledge by finding males and female students to differ on some, but not all, science attitude items.

In this study, significant differences between males and females are found on only two modified mATSI:2 items- Q1 ($p<0.05$) and Q3 ($p<0.05$) of the *Science Anxiety* factor. On both Q1 (*It makes me nervous to even think about science*) and Q3 (*It scared me to have to take a science class*) males students display low science anxiety and female students display neutral science anxiety. These results parallel previous literature that males have lower science anxiety than females (Mallow, 1994). For example, in Danish students and American university students over the age of 17, Mallow (1994) found females to exhibit more science anxiety than males. This also mirrors results from Udo et al. (2001), who examined science anxiety for students enrolled in an American introductory university physics course and found that gender contributed to science anxiety, with male students displaying less science anxiety than female students. Cho and Aye (2020) also found male students to display significantly less science anxiety than female students in a population of grade 8 students from Myanmar, displaying that this trend is well-characterized globally.

While results on items Q1 and Q3 of the *Science Anxiety* factor appear to be consistent with previous literature, they only account for half of the items within the *Science Anxiety* factor. Both male and female students exhibited low science anxiety on Q2 (*I feel tense/nervous when someone talks to me about science*) and Q6 (*No matter how hard I try, I cannot understand science*) of the *Science Anxiety* factor, displaying a more complicated relationship between gender and science anxiety. While Q1 and Q3 appear to contradict previous literature examining gender differences on science anxiety, and Q2 and Q6 appear to support previous literature (Cho & Aye, 2020; Bryant et al., 2012; Mallow, 1994; Udo et al., 2001), this difference may be due to the differences between the questions themselves. Megreya et al. (2021) found grade 11 and 12 female students displayed more science anxiety than male students. However, they also identified two factors of science anxiety – learning science anxiety and science evaluation anxiety. A significant difference was only noted in science anxiety and science evaluation anxiety, but not in learning science anxiety. This indicates that science anxiety does not always produce uniform results on all survey items, which is consistent with the results from this current study.

It is also worth noting that no item displays a median negative value of science anxiety for either males or females. This means that while the relationship between science anxiety items and gender is complex, both examined genders still display positive or neutral attitudes towards science on all items. Further research should be conducted to determine if these differences have any significant impact on student performance or future behaviour regarding science engagement.

Additionally, there is no significant difference between males or females on any items of the *Enjoyment of Science* factor. Both genders display neutral enjoyment of science for Q7, Q8 and Q9. This also contradicts previous research by Weinburgh (2000), who found that male middle school students displayed significantly higher enjoyment of science compared to females ($p<.05$). However, enjoyment of science as a factor of science attitudes has not been well-characterised in the literature. For this reason, future research should examine the *Enjoyment of Science* factor in additional populations to better characterize its relationship with student gender.

The results of this study suggest that male and female students significantly differ only on how trepidatious they were regarding science and taking science classes. As behavioural intention is the best predictor of behaviour and behaviour itself is influenced by attitudes (Fishbein & Ajzen, 2010), the results of this study suggest that male students may take future science classes and think more about science more so than female students. Previous research informs this idea, as when using the theory of planned behaviour, Moore and Burrus (2019) found that attitudes towards mathematics were significantly predictors of senior high school students' college major intentions.

Interestingly they found this effect to be slightly stronger in female students. While the current study solely examined attitudes towards science, Moore and Burrus (2019) highlight that attitudes can be significant predictors of intention.

6.4 RQ2: Can clusters be identified based on components of students' science attitudes within an introductory environmental science course?

Within this study, two meaningful clusters are identified, with two distinct profiles. The identification of clusters allows us to understand better the distinct groups of students that exist within the examined course, without establishing groups beforehand. Previous research by Pino-Pasternak and Volet (2018), identified 4 profiles on attitudes towards science learning in preservice Australian teachers – vulnerable, uncommitted, optimal and promising. Five distinct profiles were previously identified in eighth grade Hong Kong students by Ma (2022): two indicating negative attitudes towards science, one indicating neutral attitudes towards science, one indicating moderate attitudes towards science and one indicating highly positive attitudes towards science. In this study, two clusters are identified within a Canadian introductory university environmental science course – one with negative and neutral attitudes towards science and one with positive attitudes towards science.

Cluster 1

The first cluster (n=79) reflects a sample of students who display negative attitudes towards science on all *Enjoyment of Science* items (Q7, 8 & 9), and a mixed response between negative (Q1, 3) and neutral (Q2, 6) attitudes towards science on the

Science Anxiety factor items. Responses to *Science Anxiety* factor items suggest that taking science classes and thinking about science elicit science anxiety for students in this cluster. At the same time, they do not feel nervous when others talk to them about science or believe that they cannot understand science. However, these students also do not enjoy science, science assignments or have a desire to learn science content. This suggests that it is not science content that causes science anxiety in this sample of students, nevertheless, content does not elicit enjoyment for them either.

Cluster 2

The second cluster consists of a majority of students (n=118) who display a profile distinctly different from cluster 1, with positive attitudes towards science on all items. These students have a high enjoyment of science on all *Enjoyment of Science* factor items (Q7, 8 & 9). This contrasts with cluster 1 and highlights a large group of students who highly enjoy science content. Students in this study also display positive responses on all *Science Anxiety* factor items as well (Q1, 2, 3 & 6) indicating low science anxiety.

Cluster Comparison

Examining the profiles of cluster 1 and cluster 2, a few key conclusions can be made. The profile of cluster 2 suggests a majority of students taking this introductory environmental science course display positive attitudes towards science. Both cluster profiles also suggest that students do not display negative science anxiety on Q2 (*I feel tense/nervous when someone talks to me about science*) and Q6 (*No matter how hard I* *try, I cannot understand science*). This indicates that the understanding of science or discussion regarding science are not significant issues within this course. Rather, cluster 1 students are nervous when taking science classes or thinking about science content. According to tripartite theories of attitude (Fisbein & Ajzen, 2010), these results indicate that students express negative feelings towards both science content taught, and the classes themselves. As per the theory of planned behaviour, this could have negative impacts on students' intentions to engage with science content or future science classes. Ong et al. (2022) previously indicated that the affective domain of attitude towards chemistry learning was a significant factor in future intentions to enroll in courses related to chemistry. To prevent similar results for students enrolled in introductory environmental science courses, educators and policy makers should focus on reducing science anxiety for students regarding their attitudes towards science education. Further research should also be conducted to better characterize how science attitudes affect intentions to enroll in science courses.

Another area of key importance is the *Enjoyment of Science* factor, which displays low enjoyment for cluster 1 participants. This indicates there are two distinct groups of students enrolled in this course – those who enjoy science and those who do not enjoy science. Findings by Gibbons et al. (2018) provide insights into these results. Gibbons et al. (2018) found that enjoyment was positively correlated with exam performance, and that anxiety was negatively correlated with exam performance in a postsecondary organic chemistry course. Achievement is not examined within this study, but this potential relationship suggests that the low enjoyment of science found in cluster 1 participants could be problematic for student achievement and success.

Clusters identified differ from profiles in previous research by Ma (2022) and Pino-Pasternak and Volet (2018), which displayed more complex profiles than the clusters identified in the current study. Ma (2022) identified five profiles, with two profiles consisting of negative attitudes towards science – one displayed negative attitudes towards perceived competence in science and another displayed negative attitudes towards instrumental value of science and engaging science teaching.

Pino-Pasternak and Volet (2018) identify two distinct negative profiles towards learning science. The first was a “vulnerable” profile with high perceived difficulty, high anxiety, low interest, low self-efficacy, and low enjoyment towards science learning. The second was an “uncommitted” profile with low perceived difficulty, anxiety, self efficacy, interest, enjoyment, self-determination, and grade motivation. Within the current study, one cluster (cluster 1) emerged with negative attitudes towards two components of science anxiety – thinking about science and taking science classes.

Pino-Pasternak and Volet (2018) also identified two positive profiles. One profile, deemed “optimal”, displayed low difficulty and anxiety but also high self-efficacy, enjoyment, self-determination, interest, and grade motivation. The other profile was deemed “promising” and displayed high self self-efficacy, interest, enjoyment, self-determination, and grade motivation, but high perceived difficulty and anxiety. Within this study, one cluster (Cluster 2) displayed positive attitudes towards science on both enjoyment of science and science anxiety factors.

One potential reason for the more complicated profiles identified in previous research may be the complexity of the instruments used, with Ma (2022) using an instrument with four factors and Pino-Pasternak and Volet (2018) using an instrument with seven factors.

6.5 RQ2a: How do clusters differ based on gender, faculty and/or year of degree program?

Within this study, cluster 1 and cluster 2 were found to be significantly different based on faculty membership. Cluster 1, which consists of negative and neutral attitudes towards science was composed of mostly nonscience faculty students (n=78) compared to science faculty students (n=1). Cluster 2, which displays positive attitudes towards science, consists of both nonscience faculty students (n=60) and almost all science faculty students (n=58).

Cluster profiles partially coincide with our results from research question 1. While they support the result that science faculty students display better attitudes towards science, they do not find science faculty students to display better attitudes towards science than nonscience faculty students. While there are nonscience students who mostly compose cluster 1, there are still many nonscience students within cluster 2. This indicates that this study conflicts the literature stating nonscience students display more science attitudes than science students (Megreya, 2021; Robinson, 2021; Udo et al., 2004). Rather, in this study there is a sample of nonscience students who display negative and neutral attitudes towards science, and another sample that displays positive attitudes towards science. Future research should examine the individual faculties that comprise the umbrella of nonscience faculties to better characterize this difference.

Additionally, cluster profiles identified agree with Robinson (2012), who found no gender differences between science and nonscience major students at the university level. They do not, however, support previous research that finds students in different academic years to display different attitudes towards science (Impey et al., 2021; Summers, 2021; Susilawati et al., 2022).

Previous research that identified student profiles based on science attitudes (Ma, 2022; Pino-Pasternak & Volet, 2018) do not focus on post-secondary courses that allow enrollment from multiple faculties. This study begins to characterize the difference between faculties within post-secondary science courses. This study identifies that student faculty is associated with attitudes towards science in an introductory university environmental science course. Future research should aim to better characterize if faculty is associated with different science attitudes within different post-secondary science courses.

6.6 Significance of Study Findings

Research from this study expands on previous literature on attitudes towards science through an examination of student attitudes in an introductory university environmental science course. This study addresses the gaps in the literature on science attitudes in post-secondary science courses, as well as the differences between different demographics – gender, faculty, and academic year.

The results of this study indicate student faculty displays the most significant association with attitudes towards science, with nonscience students displaying significantly worse attitudes towards science than science students. Male students also display significantly more positive attitudes towards science classes and thinking about science content than female students, but this was not found to be a significant factor in clustering. However, cluster analysis only identifies complicated attitudes towards science for nonscience students, with almost half of nonscience students grouping into cluster 2, which display positive attitudes towards science. This indicates that students in cluster 1, consisting of both science and nonscience students may have higher intentions to engage with science in the future than students in cluster 2, which consist mostly of nonscience students. While at the same time gender does not influence cluster membership, despite significant previous literature indicating that it should (Cho & Aye, 2020; Bryant et al., 2012; Mallow, 1994; Udo et al., 2001). Based on these results, educators and curriculum developers can aim to further identify and target a specific subset of nonscience students who struggle with positive science attitudes in introductory university environmental science courses. Via the TPB, effective interventions developing more positive science attitudes could improve these students' intentions to engage with science in the future. Considering that university is the last time many of these students will take a science class, this is one of the last opportunities to implement targeting interventions for students with negative science attitudes.

Chapter VII: Conclusion

This study utilized a quantitative research design to examine the science attitudes of university students enrolled in an introductory environmental science course. In addition, the relationship between student gender, faculty and academic year was examined with the intention of identifying factors that influenced students' science attitudes.

The literature review noted mixed results on factors that contribute to positive science attitudes. My research found that student faculty has the most significant association with science attitudes in undergraduate students enrolled in an introductory environmental science course. In addition, upper-year students feel they can understand science significantly more than first-year students. Females also appear to be more nervous thinking about science and trepidatious to take science classes when compared to males.

In addition, this study finds that two distinct groups of students exist within this course: a group of positive science attitudes, and a group with negative enjoyment of science and mixed non-positive science anxiety. In the end, these two groups are distinguished by the faculty of cluster members, with science faculty students belonging to the positive attitude group and nonscience faculty students distributed between both groups.

My research addressed the research questions and the literature gap related to research on science attitudes in post-secondary science education. According to previous research it is unclear what the role of gender, faculty, and academic year has on student attitudes towards science. While this study does not characterize how these factors influence science attitudes, it does contribute to the literature on understanding which factors significantly influence science attitudes.

7.1 Recommendations

As a result of findings from my research, recommendations are warranted in terms of improving curriculum within introductory university science and related courses. It is recommended that science course content and assessments aimed at improving attitudes towards science are incorporated into science courses for nonscience students, and courses that historically include nonscience students. Previous research suggests a shift away from traditional tests and assignments towards a more student-centered approach could improve science attitudes for nonscience students (Kazampour & Amirshokoohi, 2013; Walczak & Walczak, 2009). Additionally, university educators and school administrators should focus on improving attitudes towards science for incoming students. This may improve their intentions to enroll in science courses and serve to reduce the science anxiety nonscience students express towards taking science classes.

7.2 Limitations

There are several limitations of the study, including limitations with generalizability, triangulation, and collected demographic data. This includes the selection of participants, which was not done randomly but was conducted via a convenience sample of participants within the singular winter 2022 section of the introductory environmental science course (Mensink, 2022). Generalizability is limited as only a single section of the introductory environmental science course is examined, within one Ontario university. Research from this study therefore may not be representative of all introductory environmental science courses, introductory science courses in general or other previous or future sections of this course.

Results from Mann-Whitney U and Chi-Square Tests also have limited ability to be generalized to populations that do not fit into heteronormative male-female roles, as education outcomes have previously been found to differ between cis-gender and gender-diverse youth (Wilkinson et al., 2021). This suggests that responses to attitude items, and the impact these responses may have on behavioural intention, may not be the same between cis-gender and gender-diverse students. Within this study, the sample size for students who did not identify themselves as male or female (n=11) was also too small to analyze.

Another limitation of this study is the absence of demographic information on participants' racial identity and Indigeneity. Previous research has found racial identity to be a potential factor in population differences regarding science attitudes (Weinburgh, 2000). In the 2022 equity census of Western University, where this study was conducted, 2.2% of its student body identified as Indigenous (Western University, 2022). Additionally, 0.3% identified as non-North American Indigenous, 2.7% South East Asian, 3.3% Latino/a or Latinx and 4.6% as Black in its 2022 equity census (Western University, 2022). Populations with typically lower membership at the university level may not have even been represented at all within this study population. This makes it is difficult to generalize results from this study to people of all racial identities and Indigeneity as the utilized survey instrument from this study did not collect information on participants' racial identity or Indigeneity.

Another limitation in this study is its timing during the science course. As this study was conducted midway through the year, it is difficult to ascertain if the course itself already had an impact on student attitudes. This study also only incorporated a quantitative methodology, thus making it challenging to understand why certain trends emerged in the data.

Additionally, the sample size for this study was not large enough (n=197) to examine individual faculties rather than a science-nonscience duality. Sample size also presented an issue with academic year. Similarly, academic year had to be reduced to a first year and upper-year duality, removing any nuance in the data. Additionally, limited ability for triangulation is possible within the present study, as only quantitative data was collected in the first survey by Mensink (2022).

7.3 Future Research

This study explored science attitudes for students in an introductory university environmental science course. As this study was conducted in an introductory course at a single Canadian university, future studies should examine science attitudes for courses at different academic levels and within student populations at different Canadian universities. Future researchers should also explore differences in science attitudes between specific nonscience faculties, as mixed results were found in this study.

To ensure all populations are fully characterized, researchers should analyze the relationship between science attitudes, racial identity and indigeneity. This will allow educators to better support underrepresented populations in the classroom. In addition, the relationship between gender and science attitudes should be further examined. Future research should examine gender-diverse students in addition to cis-gender students to better understand how their attitudes towards science and intention to engage with science differ. This will also allow the relationship between science attitudes and male-female genders in university students to be better understood, as this study found mixed results.

Additionally, as this study focused specifically on the affective domain of attitude, other domains of attitude as well as components of behavioural intention should also be examined in similar populations. This will allow educators to better understand how to engage students in science at the post-secondary level.

To extend beyond characterization of science attitudes between demographic populations, researchers should examine the impact of learner-centered approaches on students' attitudes towards science.

7.4 Concluding Remarks

In conclusion, the results of this study provide insight into the relationship between science attitudes and gender, faculty, and academic year within introductory university environmental science students. In this study, student faculty is identified as having a significant association with science attitudes. A small number of science anxiety items were also found to differ between students based on their gender and academic year. Two clusters of students were identified, one primarily consisting of nonscience students with neutral and negative attitudes towards science and another consisting of both science and nonscience students with positive views towards science. Finally, future research should examine science attitudes further at the post-secondary level and aim to better characterize the relationship between faculty and science attitudes. Additionally, university educators and school administration should focus on improving science attitudes of current and future students enrolled in nonscience faculties, as they express poor science attitudes than their science faculty counterparts.

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Appendices

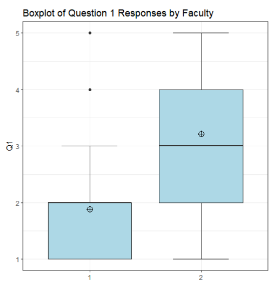
Appendix A: Additional Tables

Table A1

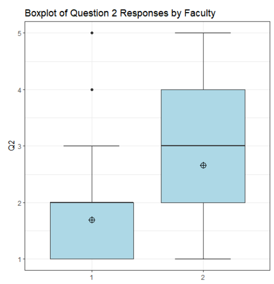
Box Plots for Modified mATSI:2 Reponses by Faculty

Science Anxiety factor items

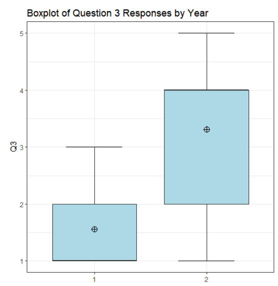
Q1



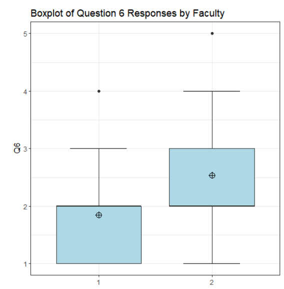
Q2



Q3

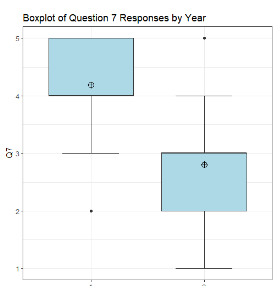


Q6

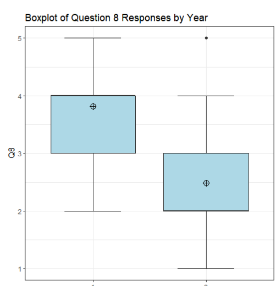


Value of Science factor items

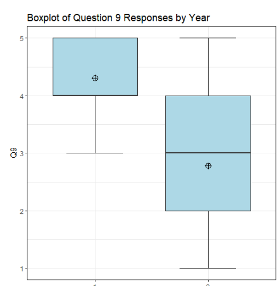
Q7



Q8



Q9



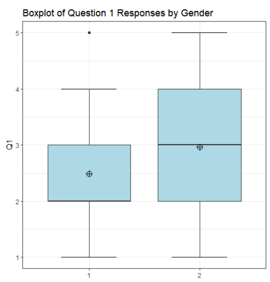
Note. The median value is respresented by a bolded line and the mean is represented by the ⊕ symbol. First and third quartiles are represented by the box ends. Whiskers reach out of Q1-1.5*IQR and Q3+1.5*IQR. Potential outliers are represented by dots beyond the whiskers. Science=1, nonscience=2.

Table A2

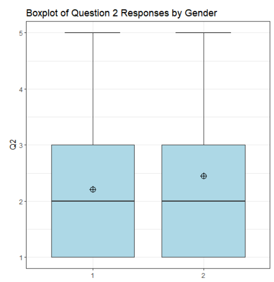
Box Plots for Modified mATSI:2 Reponses by Gender

Science Anxiety factor items

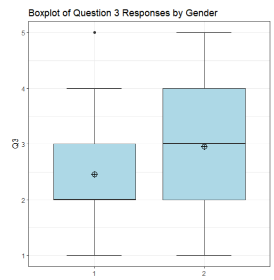
Q1



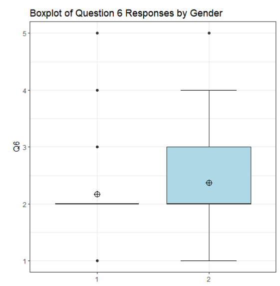
Q2



Q3

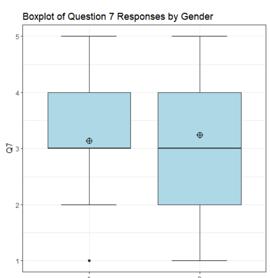


Q6

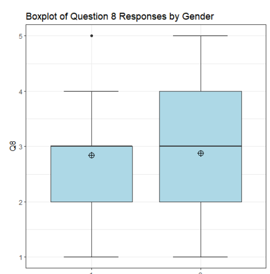


Value of Science factor items

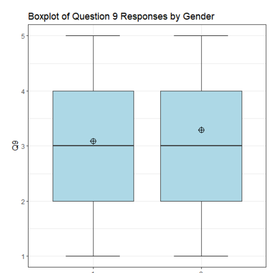
Q7



Q8



Q9



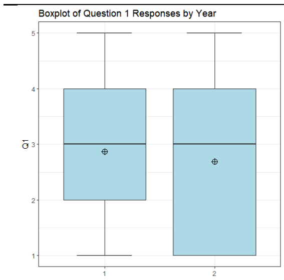
Note. The median value is respresented by a bolded line and the mean is represented by the ⨁ symbol. First and third quartiles are represented by the box ends. Whiskers reach out of Q1-1.5*IQR and Q3+1.5*IQR. Potential outliers are represented by dots beyond the whiskers. Male=1, Female=2.

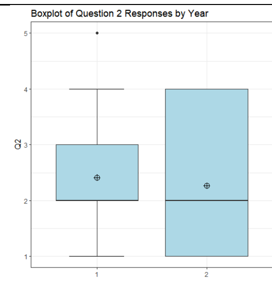
Table A3

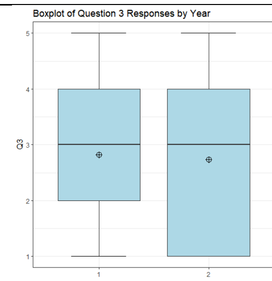
Box Plots for Modified mATSI:2 Reponses by Academic Year

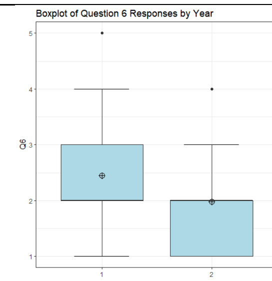
Science Anxiety factor items

Q1	Q2	Q3	Q6



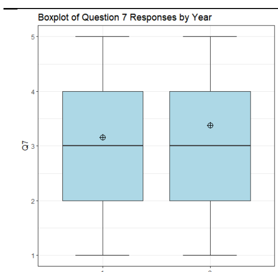


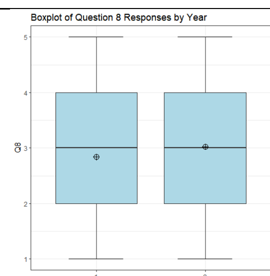


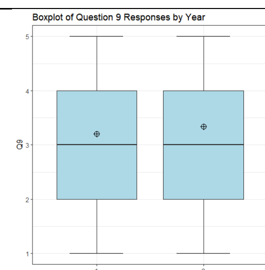


Value of Science factor items

Q7	Q8	Q9







Note. The median value is respresented by a bolded line and the mean is represented by the ⊕ symbol. First and third quartiles are represented by the box ends. Whiskers reach out of Q1-1.5*IQR and Q3+1.5*IQR. Potential outliers are represented by dots beyond the whiskers. First-Year=1, Upper-Year=2.

Appendix B: Quantitative Data Mining

Expanded Exploratory and Confirmatory Factor Analysis Methodology

Prior to identification of the factor structure, univariate normality, multivariate normality, factorability, and multicollinearity were examined to determine the best estimation method to use in CFA. Multivariate normality is assumed in most CFA estimation methods (Harrington, 2009). After analysis, the data is found to be non-normal. For this reason, an estimation method that does not require normality is selected. Diagonally weighted least square (WLSMV in RStudio), which does not assume normality, is used as the estimator to conduct CFA. The two-factor structure found by Tai et al. (2022) is examined, with the intention that failure to uphold the existing model would be followed by exploratory factor analysis (EFA) to determine underlying factors. CFA indices are used to assess whether the existing model is upheld. The most common absolute fit index examined is the model chi-square, which determines if the model is an exact fit for the population examined (Harrington, 2009). One other absolute fit index, the standard root mean square residual (SRMR) is examined, which compares correlations in the input matrix to correlations predicted by the model (Harrington, 2009). Additionally, a parsimony correction index is examined-the root mean square error of approximation (RMSEA), which assesses how well the model fits within the population reasonably (Harrington, 2009). Comparative fit indices (CFI), which evaluate the fit of the model compared to a more restricted model is also examined (Harrington, 2009). After examination of CFA results, the original factors found in Tai et al. (2022) are found to not fit the model, so EFA is conducted.

Following CFA, EFA is used to determine factors underlying items on the 9-item mATSI:2 scale. EFA is a factor analysis technique in which no factor structure is hypothesized. It aims to classify, describe, and clarify datasets (Maroof, 2012). Within EFA, factors are organized either across or within different constructs (Maroof, 2012). When organized across constructs, distinctly different aspects of an experience are determined (Maroof, 2012). However, when organized within constructs, factors varying levels of specificity within a construct are signified (Maroof, 2012). Within this study, the latter approach is taken, with the factors examined signifying aspects of science attitudes.

As the factor structure of the mATSI:2 survey was not supported by CFA, EFA is run without assumptions as to underlying factors. Results from the factor extraction methods, including scree plots, Velicer's minimum average partial (MAP), sequential chi-square (SMT), empirical Kaiser criterion (EMPKC) and parallel analysis tests, are used to determine the number of factors to extract. Within parallel analysis, eigenvalues from the dataset are compared to eigenvalues generated from a randomly generated dataset. The number of factors or components are determined where the real eigenvalues exceed the simulated eigenvalues. Within MAP, the effect of the removal of eigenvalues is examined, potentially making it more robust than even parallel analysis (Caron, 2019). For SMT analysis, multiple EFA tests are conducted with an increasing number of factors (Auerswald & Moshagen, 2019). The suggested number of factors is reported as the point where the number of factors becomes non-significant (Auerswald & Moshagen, 2019). The scree test is analogous to a visual version of an eigenvalue test. Here, the shift from a drop to a plateau of eigenvalues as factors increase is visually determined. This point, called the “elbow”, is reported as a potential factor solution (Maroof, 2012). EMPK is a sample-variant of the Kaiser criterion, and extracts factors based on eigenvalues greater than one (Auerswald & Moshagen, 2019). After examining all factor extraction methods, EFA is conducted.

EFA is conducted for both one and three factor solutions. EFA for the three-factor solution is conducted using Promax rotation, an oblique rotation method, to rotate data. For a one-factor solution, no rotation occurred. Oblique rotation methods are preferred when more than one-factor solutions exist, as they allow factors to be correlated (Maroof, 2012). EFA aims to have large loadings on one factor, and small loadings on others (Maroof, 2012) within a rotation pattern matrix. Hair (2006) (p112) proposes that for sample sizes of 150-199, items below 0.45 are non-significant on factor loading. Hence for this study, items are removed if factor loading exceeded 0.45 but no items were identified. Chronbach’s alpha was examined following this, and another round of removal occurs for data that did not meet assumptions of reliability (>0.70).

Exploratory factor analysis is then run again on the items remaining, where a two-factor solution was found. No items are removed following the second round of exploratory factor analysis. The two identified factors are *Enjoyment of Science* and *Science Anxiety.*

Expanding Cluster Analysis Methodology

Clustering techniques are widespread in the classification of distinct groups among datasets. The aim of clustering approaches is to create clusters where the items in each cluster are similar to one another, while different from items in a different cluster (Schubert & Rousseeauw, 2019).

Clustering techniques can be either hierarchical, consisting of agglomerative (start from their own separate clusters and combine), and divisive (star with one cluster and divide into smaller clusters), or non-hierarchical (Charrad, 2014). Non-hierarchical approaches begin with a pre-determined number of clusters and include techniques such as k-means and k-medoids clustering. Due to higher reliability, non-hierarchical cluster analyses are used in this study.

Two largely used non-hierarchical clustering techniques are k-means and k-medoids clustering. Here *k* clusters are created where the objects within a cluster are more alike to one another than objects within a different cluster (Abu-Jamous et al., 2015).

K-Means Clustering

K-means clustering is one of the most commonly used non-hierarchical clustering techniques (Abu-Jamous, 2015). When using this clustering technique, the within-cluster variation is minimized for the cluster solution provided. First, the data is randomly partitioned. Objects are then assigned to the nearest cluster, and the centroid of these clusters updated. These steps are repeated until there are no changes in clusters (Abu-Jamous, 2015).

K-Medoids Clustering

K-medoids clustering is very similar to k-means. Here *k* representatives, the medoids, are searched for in the dataset (Abu-Jamous, 2015). Within this study, PAM (partition around medoids) algorithm, a k-medoids clustering technique, was used due being a more robust approach compared to k-means (Mohibullah et al., 2015; Kaufman & Rousseeuw, 1990). Rather than the mean values used in k-means clustering, PAM k-medoids chooses a single representative data point among a cluster to use as the medoids (Denaro et al., 2021). This can be roughly compared to the median (Mohibullah et al., 2015) and helps reduce the influence of outliers on cluster centers. This medoid is the point in the dataset where the dissimilarity between this point and all other points in the cluster is minimized (Abu-Jamous, 2015). Within k-medoids clustering, a number of different iterations are generated. Objects are randomly assigned as medoids, and all other objects are assigned to these medoids based on the distance between the object and medoid (Abu-Jamous, 2015). This continues until the optimal clusters are determined based on distance and the number of clusters specified (Abu-Jamous, 2015).

PAM is non-parametric (Pollard & van der Laan, 2005), meaning it does not assume distribution of data. PAM has been previously used due to its ability against outliers being high (Abu-Jamous, 2015). PAM clustering is also not dependent on the order of presented data objects (Kaufman & Rousseeuw, 1990), and more resistant to outliers and noise (Sunge et al., 2020) compared to k-means clustering.

Hopkins Statistic

Prior to conducting k-medoids cluster analysis, various tests must be performed to determine if the data is clusterable, and how many clusters are optimal. First, the Hopkins statistic can be calculated to determine whether the data is clusterable. The Hopkins statistic compares the distances between randomly selected points in a dataset to their nearest neighbour and randomly generated points and their neighbours (Hopkins & Skellam, 1954). Within this study, the Hopkins package in RStudio is used to calculate this Hopkins statistic. Within this package, calculated values between 0 and 0.3 suggest that the data is regularly-spaced and not clustered (Wright, 2022). Values between 0.3 and 0.7 indicate data is randomly distributed, and values from 0.7-1 indicate that data is clustered (Wright, 2022). Cross & Jain (1982) suggest using a sample of between 10% and 20% when calculating the Hopkins statistic to avoid small sample problems.

Distance Techniques

After determining clusterability of data, when conducting k-medoids clustering, a distance technique must be selected. Two common distance techniques exist to conduct k-medoids clustering, Euclidian distances and Manhattan distances (Pranoto et al., 2022; Mohibullah et al., 2015). Euclidean distance calculates distance using squared error (within-cluster variation), while Manhattan distance calculates distance using absolute value distance (Mohibullah et al., 2015). Euclidean distances and Manhattan have both been found to be effective for use in k-medoids cluster analysis (Sunge et al., 2020). The Davies-Bouldin index can be used to determine which distance technique to use. Here the average similarity between clusters is determined, with a lower value indicating well-separated clusters (Davies & Bouldin, 1979).

Within this study, both Euclidean (DB=1.028) and Manhattan (DB=0.402) are tested using the clusterSim package in RStudio to calculate Davies-Bouldin's Index, which attends to maximize the distance between clusters (Pranoto et al., 2022). The lower the Davies-Bouldin's index value the more optimal the clustering, so Manhattan distance was used to conduct k-medoids clustering.

Silhouette Statistic

To determine the number of clusters to use in cluster analysis, the silhouette statistic, gap statistic and within-sum of square approaches can be used calculated using the NbClust package in RStudio (Charrad, 2014). The silhouette statistic can be used to determine the optimal number of clusters through comparing the average silhouette width between different cluster numbers (Kaufman & Rousseeuw, 1990). The silhouette statistic, s(i), can be calculated using the formula:

$$s(i) = \frac{b(i) - a(i)}{max\{a(i), b(i)\}}$$

The cluster with the maximum value of s(i) is determined to be the optimal cluster number (Kaufman & Rousseeuw, 1990). Cluster membership of objects can also be examined via the silhouette plot, with negative values indicating potential poor fit (Kaufman & Rousseeuw, 1990).

Gap Statistic

Gap statistics calculate intra-cluster variation (Tibshirani et al., 2001). Where the gap statistic is maximized, the optimal number of clusters is chosen. The gap statistic method for estimating cluster numbers can be applied to any clustering method (Tibshirani et al., 2001), including the PAM clustering algorithm. The gap statistic compares intra-cluster variation within the dataset to the intra-cluster variation expected for the null distribution (Tibshirani et al., 2001). This is done for different cluster numbers, and where the gap statistic is maximized the optimal number of clusters is chosen. According to Tibshirani's 1-standard-error method, the optimal cluster number can be found where the gap statistic slows down, at the smallest *k* where $Gap(k) \geq Gap(k+1) - s_{k+1}$ (Tibshirani et al., 2001).

Total Within Sum of Squares

Within cluster analysis, the total within-sum of squares (WSS) should be minimized (Kassambara, 2017) to find the optimal number of clusters. This ensures that within-cluster variation is kept to a minimum (Kassambara, 2017). For this reason, the optimal number of clusters can be determined by examining the total WSS and comparing them between different cluster numbers. The cluster selected as optimal is where adding an additional cluster does not improve the WSS much (Kassambara, 2017). This is called the "elbow method" and can be determined by graphing the total

WSS and number of clusters. Where there is a bend in the graph (the "elbow"), the optimal number of clusters can be found. As this is not always accurate, the elbow method can be combined with the silhouette statistic and gap statistic to determine the optimal number of clusters.

Appendix C: Letter of Information and Consent + Survey 1

Default Question Block

Letter of Information and Consent

Study Title: The use of applied conservation case studies in environment and sustainability education

We invite you to participate in a research study being conducted by Dr. Paul Mensink, Assistant Professor (Department of Biology, Centre for Environment and Sustainability). You may contact Dr. Paul Mensink at [redacted] or [redacted]. This work is supported by the Unity Charitable Fund, a fund of the Tides Foundation.

PURPOSE OF THE STUDY

The focus of this research is to explore how applied conservation case studies can be used in the [redacted] classroom to improve learning and engagement with lecture material.

PROCEDURES

As part of the course curriculum of [redacted], you will be asked to complete the following during this class: Complete a short lab activity on shark conservation (~45 minutes). Complete four, 5-min, anonymous surveys hosted on the Qualitrics online survey platform asking questions about the class activity. You will complete aspects of the activity prior to the completion of the surveys. In total, the four surveys should take approximately 20 minutes to complete. The answers you submit to the surveys are completely anonymous and cannot be used to link back to any of your personal information or data from the course.

As part of the survey, you will be asked to create a unique identifier code by identifying your mother's first initial - last three digits of your phone number - your month of birth. This unique code will only be used to link your responses among surveys. If you volunteer to participate in the study, you will be randomized into an experimental group and your anonymous survey responses will be used in the research study. You will not be identified directly or indirectly at any point in the study. Your survey responses will only be accessed for research purposes after the final grades for the course have been submitted.

INCLUSION CRITERIA

If you volunteer to participate in this study, you must be enrolled in [redacted]. Participants will have to complete certain tasks prior to the completion of the surveys and will need to download a mobile phone application to complete the study. Students with auditory disorders will be excluded from the study but are still able to participate in the activity.

COMPENSATION FOR PARTICIPATION

You will be given 2% of your overall course mark in [redacted] for completing the activity and surveys.

POTENTIAL RISKS AND DISCOMFORTS

There are no known physical or psychological risks or discomforts associated with this research.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You may not directly benefit from participating in this study but information gathered may provide benefits to society as a whole which include helping to mentor the new generation of university instructors to create more engaging and effective teaching environments for students. The ultimate goal of our research is to identify effective technology that instructors may use to support the learning of all students in diverse classrooms.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Your survey responses will be collected anonymously through a secure online survey platform called Qualtrics. Qualtrics uses encryption technology and restricted access authorizations to protect all data collected. In addition, Western's Qualtrics server is in Ireland. The data will then be exported from Qualtrics and securely stored on Western University's server. All data will be confidential, and maintained in a secure environment for at least seven years.

Representatives of The University of Western Ontario NonMedical Research Ethics Board may require access to your study-related records to monitor the conduct of the research.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may stop participating at any time. You may also refuse to answer any questions you don't want to answer and still remain in the study. If you choose not to participate, decide to stop participating, or elect not to answer specific questions, it will have no effect on your academic standing. After completion, if you would like to withdraw yourself from the study you can contact the study team and your withdrawal from participation will be done so in a timely manner. This can be done up to and prior to the publication of the results. In order to successfully withdraw your data, you would need to recreate your unique identifier code by identifying Mother's first initial - Last three digits of your phone number - Your month of birth.

You do not waive any legal right by signing this consent form.

CONFLICT OF INTEREST

The researchers do not wish to declare any conflicts of interest.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

The results for the study will be available by request from the instructor after the results are published (~December 2022).

SUBSEQUENT USE OF DATA

If you consent to the study, your anonymous survey data may be used in subsequent studies, in publications and in presentations.

RIGHTS OF RESEARCH PARTICIPANTS

If you have any questions about the conduct of this study or your rights as a research participant, you may contact the Office of Human Research Ethics at [redacted] or [redacted]

If you have questions, comments, or concerns regarding this study, or would like further information, please feel free to contact Paul Mensink at [redacted] or [redacted].

This letter is yours to keep for future reference and can be accessed here.

I give permission for Dr. Mensink and his colleagues for my anonymous survey responses to be included in the research study for research purposes once final grades for the course have been submitted:

- ○ Yes
- ○ No

Please create a unique identifier for yourself by combining the following:

[redacted]

If you have not consented to the use of your anonymous survey data for the research study, your unique code above will identify your survey results for exclusion from the research project.

Demographic information

In the space below, please indicate which gender you most identify.

What is your primary faculty?

- ○ Arts and Humanities
- ○ Richard Ivey School of Business
- ○ Education
- ○ Engineering
- ○ Health Sciences
- ○ Information and Media Studies
- ○ Law
- ○ Schulich School of Medicine & Dentistry
- ○ Don Wright Faculty of Music
- ○ Science
- ○ Social Science
- ○ I prefer not to answer

What year of study are you in?

mATSI:2

Please complete the following questions.

It makes me nervous to even think about doing science

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree
- ○ I prefer not to answer

I feel tense/nervous when someone talks to me about science

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

It scares me to have to take a science class

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

Science is useful for solving the problems of everyday life

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

Science is helpful in understanding today's world

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

No matter how hard I try, I cannot understand science

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

Science is something which I enjoy very much

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

I like the challenge of science assignments

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

I have a real desire to learn science

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- I prefer not to answer

Non-consenting students

Please proceed to break-out room #1.

Consenting students

Please proceed to break-out room #1.

Please proceed to break-out room #2.

Please proceed to break-out room #3.

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Curriculum Vitae

Name:	Rajan Brar
Post-secondary Education and Degrees:	The University of Western Ontario London, Ontario, Canada 2015-2019 B.Sc.
	The University of Western Ontario London, Ontario, Canada 2019-2021 B.Ed.
Honours and Awards:	Don Galbraith Pre-Service Teacher Award of Excellence 2021
Related Work Experience	Graduate Research Assistant The University of Western Ontario 2021-2022
	Secondary School Teacher Dunbarton High School 2022-2023

Publications:

Mensink, P., Brar, R., Sajid, A., & Decoito, I. (2022). Marine XR: The impact of an immersive learning AR app on student motivation and engagement with the biology, ecology and conservation of basking sharks. *Immersive Learning Research - Practitioner*, *1*(1), 67–70. https://doi.org/10.56198/A6PFY4TUG

Presentations & Workshops:

Brar, R., & Decoito, I. (2022, April 1-3). *The prevalence of digital art within Canadian secondary school curriculum* [Poster session]. The 13th Robert Macmillian Symposium in Education, London, ON, Canada.