Redeveloping an introductory plant sciences course: content, competencies and barriers to change

by

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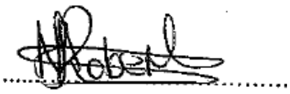
Abstract

The need to produce well-trained graduates that are capable and competent enough to enter the working world and tackle the problems they will be facing has never been greater. In light of some departmental changes and a national call for the transformation of university curricula, the decision to reform the introductory plant sciences course at the University of Pretoria was taken. The aim was to produce a course that is of an international standard, by aligning the course with the *Vision and Change* document, but also to ensure the content remains relevant and locally applicable. Using the Delphi Technique, this study aimed to determine broad learning objectives for an introductory plant science course, in terms of content and competencies, based on the opinion of plant science lecturers from top universities around South Africa. The Delphi Technique involves asking a series of questions, over a number of iterations, to a group of experts with the goal of reaching a consensus amongst the experts' opinions. Secondly, I aimed to explore the potential barriers that could arise throughout the process of implementing curricular changes in an introductory plant science course. Results indicated a clear majority of opinions within the participants with regards to the inclusion of specific areas of content in the curriculum as well as in the inclusion of the process of science as a competency. Results also indicated a clear majority in regard to the purpose of an introductory plant science course being to spark interest in the field rather than instil basic knowledge. The exploration of the potential barriers to change show a number of common themes. The data suggest that the largest barrier to change is found in resistance to change from lecturing staff, followed by meeting specific curriculum and institutional requirements. Limitations to change due to issues around students, such as large classes and under-preparedness are also discussed. Further studies should aim to include industry representatives in the discussion in order to help increase student preparedness in the work place, as well as creating more specific learning objectives for the course.

Declaration

I, Megan Jennifer Roberts, declare that the thesis/dissertation, which I hereby submit for the degree Master of Science (Science Education) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: 

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"Now to him who is able to do immeasurably more than all we ask or imagine, according to his power that is at work within us, to him be glory in the church and in Christ Jesus throughout all generations, for ever and ever! Amen." – Ephesians 3:20-21

Thank You Lord, for doing immeasurably more than all I ever asked and all I could ever dare to imagine.

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General Introduction

In the mid-18th century, the world changed forever with the introduction of mechanisation using water and steam for the purposes of more efficient manufacturing (Penprase, 2018); the first industrial revolution. The mid-19th century brought with it the invention of electricity, once again expanding the worlds industrial capabilities; the second industrial revolution (Mohajan, 2019). The mid-20th century and the invention of the Internet brought with it a world of easily accessible information; the third industrial revolution (Smith, 2001). Each of these industrial revolutions caused massive change in all spheres in the world; economies grew, science and technology advanced, standards of living increased, industries changed and so did education (Smith, 2001; Bekker, Hornung & Woessmann, 2010; Penprase, 2018).

In the world we live in, science and technology are evolving at an astonishing rate. Currently, the 21st Century is staring the fourth industrial revolution straight in the face (Schwab, 2016), but without knowing exactly what will come of it we cannot know how to react or how to prepare. We do however know that it will change jobs and industries and that it will change the skills we need to work in them (Helmi, *et al,* 2019). It is also clear that we will need to transform how we currently approach Science, Technology, Engineering and Mathematics (STEM) education, in order to ensure that students are prepared for the future industries they will be working for (Helmi, *et al,* 2019).

Aside from being unprepared for the effects of rapid scientific and technological expansion, we face issues regarding scientific illiteracy and a loss of students from the STEM pipeline. The National Research Council of America (1996) summarises the definition of scientific literacy as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.” Essentially, scientific literacy is knowing about and understanding science on a level that allows us to use it to make decisions in all spheres of our lives (Tomovic, *et al,* 2017; Rosenthal, 2020). Scientific literacy is a necessary outcome of an undergraduate science degree if we are to produce a workforce that can cope with the challenges of modern-day life (AAAS, 2011). The effects of having a scientific illiterate population are far reaching; influencing political decisions regarding response to climate change (Stehr, 2015), a lack of funding for already underfunded research fields such as botany (Uno, 2009) and the economic growth of a country (Uno, 2009; Aikenhead, et *al*, 2011). Recently, we saw how dangerous the impact of scientific illiteracy can be in a very digital world with the spreading of misinformation regarding the Covid-19 pandemic (Serpa, *et al*, 2021).

Similar to scientific literacy, STEM education is recognised as being an essential part of economic growth and development of a country (Freeman, *et* al, 2019). However, there have been global reports of countries with shortages of workers within the STEM field and that are not producing enough STEM graduates to meet the ever-growing demand (Zaza, *et al,* 2019; Zaza, *et al, 2020;* De & Arguello, 2020; Malik, *et al,* 2021). In both the United States and South Africa, this shortage has been linked to a decrease in STEM enrolment in tertiary institutions as well as increased attrition in undergraduate STEM disciplines (Abe & Chikoko, 2020; De & Arguello, 2020). It has been suggested that this problem is being fed by scientific illiteracy and disinterest in science from the general population (Uno, 2009), however there are multiple factors that implement students' decisions to pursue STEM disciplines, including gender, socio-economic background, race, social and familial pressures and personal beliefs (Buschor, *et al,* 2014; Rainey, *et al,* 2018; Abe & Chikoko, 2020). Although there is some dispute whether or not the STEM crisis really is a crisis or not (Smith, 2017), if it is real and if we are not managing to meet the needs of current STEM fields, how are we going to cope as the fourth industrial revolution continues to develop and change the world around us?

Aligning itself perfectly with the change taking place throughout the rest of the world is the incredible expansion of the field of biology (Cheeseman, *et al,* 2007). The advancement of technology has changed how numerous fields conduct research, the field of biology being one of them (Eaton, *et al,* 2020). The advances of technology have been hugely beneficial in the field of plant sciences. The study of plant sciences remains of critical importance due to its role in agriculture and food security, plant diversity under the threat of climate change, and the development of new medications. Despite the seemingly obvious importance of plant sciences, we are living in a world that suffers from "Plant blindness" (Wandersee and Schussler, 2001). Plant blindness, now known as Plant Awareness Disparity, can be considered a very specific form of scientific illiteracy, which has a wide range of impacts much like the impacts of scientific illiteracy mentioned above.

In their article addressing the biology curriculum in the 21st century, Cheeseman and colleagues (2007) perfectly summarise the problems we are currently facing:

"Against this backdrop of expanding knowledge comes the increasingly difficult task of training future biologists. Within a four-year undergraduate curriculum, it is impossible to study all of the vast expanse of science we know as biology, so questions arise: What is most important? What should a 21st-century biologist with a bachelor's degree know? What skills should he or she have?".

It is these very questions that inspired the study undertaken below.

In 2019 the Department of Plant and Soil Sciences at the University of Pretoria, South Africa, began the task of redesigning their introductory plant science course. The goal was to create a course that not only meets international standards by aligning the course with the *Vision and Change* document (AAAS, 2011), but also to create a course that is relevant and locally applicable. Professor G. E. Uno (University of Oklahoma) hosted a series of workshops in this regard, with the focus on curriculum development and teaching strategies for members of the Department of Plant and Soil Sciences at the University of Pretoria. Because this course is run specifically at the University of Pretoria, it was only the Department of Plant and Soil Science lecturing staff at the University of Pretoria that contributed to the redesign, spearheaded and driven by key lecturing staff members.

A. Aims and objectives

In light of the recent changes at the Department of Plant and Soil Sciences at the University of Pretoria, coupled with the recent international call for reform within higher education system (AAAS, 2011; Armstrong, 2016), the decision was taken to explore the idea of change within introductory plant science courses on a national scale. The aim of this study was to identify key curricular components in introductory plant science courses as well as the barriers that could hinder curricular redesign.

Specifically, my research questions are:

1. What core concepts and core competencies should be included in an introductory plant science course?
2. What barriers could arise throughout the process of implementing curricular changes in an introductory plant science course?

The objective of this study is to establish core concepts and competencies to be used when redesigning introductory plant science curricula that ensure the course remains both nationally applicable and of an international standard. In order to maintain an international standard, I used the *Vision and Change* document (AAAS, 2011) as the foundation for identifying core concepts and core competencies. The inclusion of plant science lecturing staff from universities across South Africa assists in ensuring these concepts and competencies remain locally applicable and relevant. Furthermore, I aimed to determine what barriers to change may arise during the curricular redesign process.

Due to the broad nature of the research questions, this dissertation will be written as two separate chapters, with each chapter addressing one of the research questions. Each chapter discusses methodologies and results specific to answering each research question, however, some information between the two chapters may overlap or be repeated. In the interest of minimising the amount of repetition, aspects of the study that remain the same within both chapters are discussed below in sections B through C).

B. Universities in a South African Context

South Africa has 26 public universities that are associated with Universities of South Africa, a representative council for higher education institutions. Of these 26, seven are classified as University of Technologies. A University of Technology focuses on practical and career-oriented learning as opposed to traditional universities that are more theory based and focus on specialised training in a specific field (Farham, 2015). University of Technologies offer certificates and diplomas and may offer a small number of bachelor degrees, while traditional universities offer bachelor degrees as well as specialised postgraduate studies (Farham, 2015). The remaining 19 traditional universities are scattered around South Africa, with the oldest being the University of Cape Town which was founded in 1829 and the newest being Sol Plaatje University which was founded in 2014.

The research for this study is based at the University of Pretoria (UP). UP is a research-intensive university that offers a wide range of study programmes and has a large undergraduate student body, consisting of 37 000 students in 2022 (University of Pretoria, 2023). The introductory plant science course falls within the University's multifaceted Department of Plant and Soil Science. The course is a compulsory subject for biological science-based degrees in the Faculty of Natural and Agricultural Science and is a large enrolment course (900 students per semester). The student body is very culturally diverse, catering to both national and international students, as well as economically diverse, offering places to students from both low- and high-income families. Similar to the University of Pretoria, most traditional universities in South Africa have large, diverse student bodies and offer a wide range of study programmes, ranging from engineering, law, the sciences and theology, amongst others and are research intensive.

C. Participant Sample

The sample group for this study was a purposefully chosen group of 23 individuals from 11 universities across South Africa (Table 1). I chose to not include Universities of Technology in my study due the difference in focus between them and traditional universities. Of the remaining 19 traditional universities in the country, I identified those that had a department comparable to that of the Department of Plant and Soil Sciences at the University of Pretoria. Universities that had only agricultural or applied plant sciences departments were also excluded from the study, as were universities that did not offer plant sciences/botany as a degree or have an introductory plant science course.

Our sample group was defined as “Plant Scientists/Botanists who currently lecture plant science or have lectured plant science courses throughout their careers.” Individuals that fell within this definition were contacted using details found on their respective departmental webpages and asked to participate. Participants were included in the study based on their willingness to participate.

The study also aimed to identify core competencies that should be included in an introductory plant science module. As this study was part of a larger initiative, the scope was limited to academia and industry was not included here.

Table 1: Table showing the universities that were included and excluded from the study as a result of staff members willingness to participate.

Agreed to participate	Declined to participate
University of Pretoria	University of the Witwatersrand
Rhodes University	Nelson Mandela Metropolitan University
University of South Africa	University of Fort Hare
University of Western Cape	
Stellenbosch University	
University of Kwa-Zulu Natal	
University of Cape Town	
North West University	
University of Zululand	
University of Johannesburg	
University of the Free State	

In order to obtain a clearer picture of who my experts are, they were asked a number of questions pertaining to their demographics. The demographic information obtained from the online survey indicates that the majority of the participants (n = 21, of the original 23) identified their ethnic group as Caucasian (Caucasian = 75%, Black African = 10%, Coloured = 5%, Indian = 5%, Unspecified = 5%) and had been lecturing in the field of plant sciences for 11 years or more (11 + years = 66.67%, 0 – 5 years =

23.81%, 6-10 years = 9.52%). The gender distribution was slightly skewed towards females with them making up 52.38% of the group (males = 47.62%).

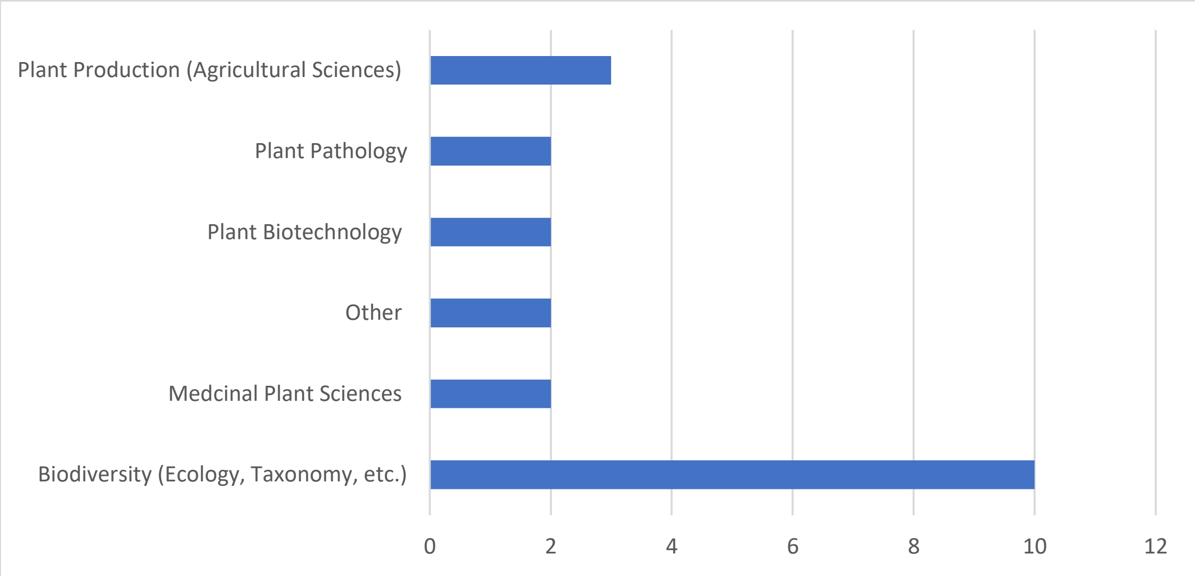

Figure 1: Distribution of participants within the 6 fields of research.

As part of the demographic information, participants were asked to place themselves into one of six groups indicating their field of research (Figure 1). Results indicated that the majority of participants work in the area of "Biodiversity" (n = 47.62%) followed by the area of "Plant Production" (n = 14.29%).

Finally, to identify if any participants had background knowledge on the *Vision and Change* document, the participants were asked if they had ever heard of the *Vision and Change* document before being contacted by the researchers. 68% of participants responded no. 18% of the respondents misunderstood the question for asking about a general concept of vision and change. However, once explained to them, eight of the 23 participants stated that the document was a good framework to use as a guide when updating or modifying a curriculum.

1. Chapter 1 – Concepts and Competencies

1.1 Introduction

This chapter focuses on the knowledge and skills a first-year student majoring in Plant Sciences at the University of Pretoria should have after a first-year Plant Science course. The heart of this chapter is that I want to know what we need to teach undergraduate students that will give them the knowledge and skills to enter the working or postgraduate world and be successful. This is a massive undertaking, and is influenced by several aspects, but I chose to focus first on one issue addressed by research question 1 (RQ-1)

RQ-1: What core concepts and core competencies should be included in an introductory plant science course?

To answer this question, I looked to the expertise of those who are recognised in the field of Plant sciences not only as researchers but also individuals who have experience in teaching Plant sciences on a higher education level. Along with the expertise of fellow academics, I used the Vision and Change document (AAAS, 2011) as a guide.

1.2 Literature Review

"Changing educational practice has never been more critical, but has likely never been more difficult" (Mclaughlin & Mets, 2016). Technology is rapidly evolving and changing how we conduct research (Eaton, *et al,* 2020). Jobs are changing, graduates are leaving university without the proper skill sets to make them productive in society and as a result are unemployable (Armstrong, 2016). Furthermore, the current workforce is constantly being required to further their education to stay up-to-date with their skills (Armstrong, 2016). The most educated generation in history is approaching retirement and we do not have enough people in the system to replace them, assuming the jobs they are leaving behind remain the same (Armstrong, 2016).

Whichever way you look at it, the environment of higher education is changing and presenting us with a long list of new challenges but also opportunities for innovation (Armstrong, 2016; Eaton, *et al,* 2020). This, along with a myriad of other factors, has headed the recent calls for change in the higher education systems which has resulted in universities around the globe needing to rethink their curriculum and teaching practices (Armstrong, 2016; Bush, *et at,* 2016; Annala, 2021; Stephen, *et al,* 2022)). The *Vision and Change: A Call to Action* document (AAAS, 2011) is one of the outcomes of calls for reform and describes a proposal to transform undergraduate biology education with the emphasis on evidence-based teaching (Brownell and Tanner, 2012; AAAS, 2011). Vision and Change encourages educators to impart skills to students to fully prepare them for making a contribution to the working world and scientific society (McLaughlin & Mets, 2016). Research suggests that curricula focusing on both knowledge and skills (competency-based curricula) and those integrating multiple subjects into a class (interdisciplinary curricula) are more likely to have a tangible impact on the societal problems we are facing than the more traditional curriculum we currently depend on (Annala, 2021; Caspersen, *et al,* 2017; Gantogtokh and Quinlan 2017). Specifically for biology education, it has been noted that there is a need for quantitative and computational education, focusing on areas such as statistical inference and modelling that is now at the forefront of biology research and application (Eaton, *et al,* 2020).

1.2.1 *Vision and Change*: A Call to Action

As the framework for the development of the curriculum I chose *Vision and Change* as a guiding document. The document entitled "Vision and Change: A Call to Action" was published by the American Association for the Advancement of Science in 2011. The compilation of the document started in 2006, whereby biology faculty, stakeholders and administrators from around the United States were brought together with the aim of improving undergraduate biology education to ensure that graduates were prepared for the future.

One of the main recommendations by the authors is the implementation of more student-centred practices and teaching methods (Auerbach & Schussler, 2017a) as well as process skills (Auerbach and Schussler, 2017b). *Vision and Change* also encouraged an interdisciplinary approach to gateway courses within the sciences (Brewe, *et al,* 2013).

The authors note that the evolution of the biology field, emerging global challenges and the innovation needed to solve these challenges, requires biologists to have different knowledge and skills to what has previously been expected of them. The document proposes five core concepts (see section 1.2.2) and six core competencies (see section 1.2.3) to be used a framework when developing new curricula. It is these core concepts and competencies that are used for the purpose of this study. These core concepts and competencies were originally developed for the undergraduate biology education in the United States; however, the broad concepts and competencies can be applied to other disciplines and other countries just as effectively as the broad discipline of biology. Although these broad concepts and competencies are helpful, it was suggested that each discipline work with these to develop discipline specific outcomes.

1.2.2 Core Concepts

1. Evolution – "The diversity of life evolved over time by processes of mutation, selection and genetic change."
2. Structure and Function – "Basic units of structure define the function of all living things."
3. Information flow, exchange and storage – "The growth and behaviour of organisms are activated through the expression of genetic information in context."
4. Pathways and transformations of energy and matter – "Biological systems grow and change by process based upon chemical transformation pathways and are governed by the laws of thermodynamics."
5. Systems – "Living systems are interconnected and interacting."

1.2.3 Core Competencies

1. Ability to apply the process of science – "Biology is evidence based and grounded in the formal practices of observation, experimentation and hypothesis testing."
2. Ability to use Quantitative Reasoning – "Biology relies on applications of quantitative analysis and mathematical reasoning."
3. Ability to use modelling and simulation – "Biology focuses on the study of complex systems."
4. Ability to tap into the interdisciplinary nature of science – "Biology is an interdisciplinary nature of science."
5. Ability to communicate and collaborate with other disciplines – "Biology is a collaborative and scientific discipline."

6. Ability to understand the relationship between science and society – “Biology is conducted in a societal context.”

The compilation of the *Vision and Change* document by a broad community of biology scientists and educators not only ensures its reliability but also ensures that when applied in the context of this project that the international standard of the course will be upheld. The Vision and Change document (AAAS, 2011) has been used as a guide for curricular change in other higher education institutions (Auerbach & Schussler, 2017a; Auerbach & Schussler, 2017b; Jardine, *et al,* 2017). Alongside being a guide for curricular change, it has been the inspiration to other documents that aim to implement curricular change such as the BioCore Guide.

The *BioCore Guide* was developed in 2014 by Brownell and colleagues. The *BioCore Guide* aimed to interpret what the core concepts listed in Vision and Change meant for individuals studying general biology degrees. The core concepts of Vision and Change are very broad, which may pose a challenge to educators who are trying to use them for curriculum reform (Cary & Branchaw 2017). The *BioCore Guide* broke the larger concepts of Vision and Change into central cross disciplinary themes, called “principles” and a series of “statements” that served as more specific interpretations of Vision and Change that spanned the larger scale of biology; from molecules to ecosystems (Brownell, *et al,* 2014). Brownell and colleagues used the Grassroots approach to develop the *BioCore Guide*, an approach similar in methodology to the Delphi Technique. Through a process of validation, Brownell and colleagues identified that 95% of respondents indicated that the “principles” in the *BioCore Guide* were important to the general biology curriculum (Brownell, *et al,* 2014). Although there were many more iterations in the Brownell study than in the current study (Brownell, *et al,* 2014), this study indicates that in the world of curriculum reform research, it is possible to achieve consensus or agreement among research participants. This work was further complimented by Cary and Branchaw (2017) who developed a “Conceptual Elements Framework” which gave further detail to the core concepts of Vision and Change. Similarly, to the BioCore Guide, a BioSkills Guide was developed to help interpret the core competencies of Vision and Change (Clemmons, *et al,* 2020).

1.2.4 What is a Curriculum?

If this study is looking at changing or improving a curriculum, it is important that we understand what a curriculum is. Curriculum is much more than a list of key topics and facts. A curriculum is influenced by the institution, the society it is created in and the historical context it survives, as well as the personal objectives of those in power (Annala, *et al,* 2016). It has been described by some as a “complicated conversation” (Pinar, 2004) or a “interactive social process” (Annala, 2021). The University of Delaware lists 44 definitions of curriculum, some of which include “Curriculum is the expectations for what will be taught and what students will do in a program of study. It includes teacher-made materials, textbooks, and national and state standards.” As well as “Curriculum is the gathered information that has been considered relevant to a specific topic. It can always be changed or added to in order to become relevant to the times.” (Delaware University, n.d.).

It has been noted that implementing the changes to a renewed curriculum is far more difficult than renewing curriculum itself (Barnett and Coate,2005; Cooper, 2017). In order to ensure that any change is implemented, we need to understand the challenges we are facing, and overcome them (Cooper, 2017). The Australian Learning and Teaching Council (2010) state that curriculum development projects are “expected to develop and model contemporary curricula that meet student and employer needs and provide the basis for on-going personal and professional development for students.” This mirrors the goals of this study.

1.3 Methodology

This section describes the methodologies and procedures used to investigate which core concepts and core competencies should be included in an introductory plant science course. Using the Delphi technique, I have compiled opinions from experts in the field of plant sciences regarding what they believe should broadly make up the learning outcomes of the course in question. The *Vision and Change: A Call to Action* report (AAAS, 2011) is the foundation of the research, providing us with a broad set of learning outcomes to work with. The use of the Vision and Change document allows us to ensure that the learning outcomes for both the concepts and competency groups are upholding an international standard. The use of local plant scientists/botanists ensures that the learning outcomes remain locally/regionally applicable and suitable for our unique South African context.

1.3.1 Researcher Context and Role

Prior to this study I completed my BSc Honours degree with my dissertation focusing on Plant Blindness (now known as Plant Awareness Disparity (Parsley, 2020)) using qualitative methods. During the initial stages of this study, I completed a Research Methodologies course (NMQ 745) exposing me to qualitative research practices. I acted as an academic tutor for the module in question, Plant Biology (BOT 161), between the years of 2020 and 2022. I was directly involved in the collection and analysis of the data for this study. To ensure my interpretation of the data was unbiased, I asked a fellow education researcher to review my work in a peer debriefing process, discussed later in this section.

1.3.2 Research Context

The main research site for this study was the University of Pretoria, South Africa. The university is a research-intensive university that offers a wide range of study programmes and has a large undergraduate student body. UP caters to a large and diverse student body that is comprised of national and international students as well as students who come from varied socio-economic backgrounds.

This study will take place within the university's multifaceted Department of Plant and Soil Science, and will be specifically looking at their first-year plant science course (BOT 161). The course is a compulsory subject for biological science-based degrees in the Faculty of Natural and Agricultural Science and is a large enrolment course (approximately 1000 students in a semester). In 2020, the course was taught by 5 lecturers, each dealing with a different topic. The topics covered in this course included:

1. Plant structure and function
2. Phytomedicine
3. Plant diversity and classification
4. Plant ecology and
5. Plant molecular biology

Along with content, the students had to attend and participate in 6 scheduled practical sessions. Each session emphasizes a section of theoretical work covered during lecture time; these sections include Plant Structure and Function, Phytomedicine, Plant Diversity and Classification, Plant Ecology and Plant Molecular Biology. Prior to the COVID-19 pandemic, these sessions would take place in a laboratory and students would be required to complete a task during the session. During the COVID-19 pandemic, these sessions were moved online and took place in the form of a lecture and students were required to complete a task over the days following the session, or they were required to write a small test, conducted in an online format.

Discussions amongst staff and faculty regarding the redesign of the course started prior to the commencement of the project, including a departmental workshop hosted by Prof Gordon E. Uno which introduced Vision and Change. The need for change was prompted by low enrolment in the plant science-based degrees. Prof Uno facilitated various discussions around the redesign of the course on a departmental level and also with key individuals who spearheaded the redesign and its implementation.

1.3.3 Using Qualitative Research Methods

Qualitative research relies on the extraction of knowledge from a purposefully chosen group of individuals in order to apply this knowledge to a specific scenario (Ulrich, 2018). Qualitative research has a number of research designs, one of which is a case study.

Case studies allow for an in-depth exploration of a phenomenon, using a number of data collection techniques (Creswell, 2014). In this study, open-ended interviews and questionnaires, over a continued period of time (Creswell, 2014) were used. The use of a case study design is ideal for this study for one main reason; collecting high quality, in-depth information about the questions at hand is of paramount importance. Like many types of studies, there are a number of features that are considered by researchers to be unique characteristics of case studies (Hatch, 2002 in Hancock & Algozzine, 2006):

1. Case studies focus on a specific phenomenon,
2. The phenomenon is researched in its natural space and during its natural time,
3. The information obtained is in-depth and comes from various sources, resulting in very descriptive research, and
4. Case studies seek to explore phenomena rather than prove relationships/hypotheses.

Based on the above-mentioned criteria, this study aligns with what is considered to be the necessary features for a case study.

Qualitative data studies use interviews, focus groups and observations as the main mode of data collection, which allows for a more in-depth understanding of participants' views (Barrett and Twycross, 2018; Brady, 2015). Interviews, as used in this study, typically use open-ended questions that are designed to gain insight into the participants "true knowledge" (Tekane, 2016) and typically generate a large amount of data (Austin and Sutton, 2015). The generation of large amounts of data allows for mixed methods research; which is characterised by different types of research in the same study as seen in this project (Austin and Sutton, 2015). This study uses both qualitative and quantitative data and so is classified as a mixed methods study.

1.3.4 Theoretical Framework

A theoretical framework is a guide for a researcher to use in their study that is based on the thoughts and publications of researchers in that respective field, with the aim being to guide us in choosing my methodologies and how I interpret my data (Grant & Osanloo, 2014; Kivunja, 2018).

I approached this study with a pragmatic worldview, using the Delphi Technique as my methodological framework. Creswell (2014), describes a worldview as "a basic set of beliefs that guide action". Pragmatism as a world view comes in various forms and many authors have discussed these forms in their papers (Rossman & Wilson, 1985; Murphy, 1990 & Cherryholmes, 1992; Biesta, 2009) but in essence, pragmatism plays an important role on placing focus on the research questions, and allows researchers the freedom to use pluralistic approaches to address research questions (Patton, 1990; Morgan, 2007 & Tashakkori & Teddlie, 2010 in Creswell, 2014). It is for this reason that this study was conducted using a pragmatic approach; in order to use the best suited techniques to answer my specific questions.

1.3.5 Delphi Technique

The Delphi Technique was identified as the most appropriate technique for this study as it has been used in similar educational studies (Sitlington & Coetzer, 2015) and is frequently used in the medical field, management studies and engineering education (Beiderbeck, *et al,* 2021, Hirschhorn, 2019), as it is well suited to collecting data from large groups of individuals and using this information to identify consensus of opinion among experts. Furthermore, it has been identified as being well suited to a study with a pragmatic world view, for several reasons, including; its flexibility, affordability, purposeful sampling, and simplicity (Brady, 2015).

The Delphi Technique is a methodological framework that is used to obtain consensus of opinion from a group of experts by means of structured communication (Van der Linde, *et al,* 2005; Thangaratinum & Redman, 2005; Skulmoski, 2007; Devaney and Henchion, 2018). It is best applied to questions were the judgement and intelligence of a collection of individuals are of more benefit to solving the problem than that of more specific analytical techniques (Kezar & Maxey, 2014). This technique is considered a suitable method for approaching curriculum development (Thangaratinum & Redman, 2005, Kezar & Maxey, 2014). Researchers (Rowe & Wright, 1999; Skulmoski, 2007; Davidson, 2017) describe the Delphi Technique as having a number of defining features:

1. Participants are experts in the field of question,
2. Participants remain anonymous to the rest of the panel,
3. Iterations over time allow participants to refine their views,
4. Controlled feedback informs individuals of the other participants' perspectives,
5. Statistical accumulation of group responses allows for quantitative analysis, and
6. The end goal is to reach consensus on an appropriate solution to a problem.

The basic format of a Delphi questionnaire (annotated graphically in figure 2) involves asking open-ended and closed-ended questions to a selection of experts. The responses are then analysed in a qualitative manner, usually by categorising responses into common themes. These analysed responses are then used to compile the second questionnaire, which is more specific than the first. Each iteration gives experts an opportunity to change their responses and view feedback from other responses, which often leads to the convergence of opinion (Thangaratinum & Redman, 2005; Skulmoski, 2007).

Experts can be defined as "people who have knowledge about the topic of concern." (McMillan, *et al,* 2016) or as an individual who has "the appropriate education background and work experience" (Davidson, 2017). For the purpose of this study, I have chosen to define my group of experts as "Plant Scientists/Botanists who currently lecture plant science or have lectured plant science courses throughout their careers."

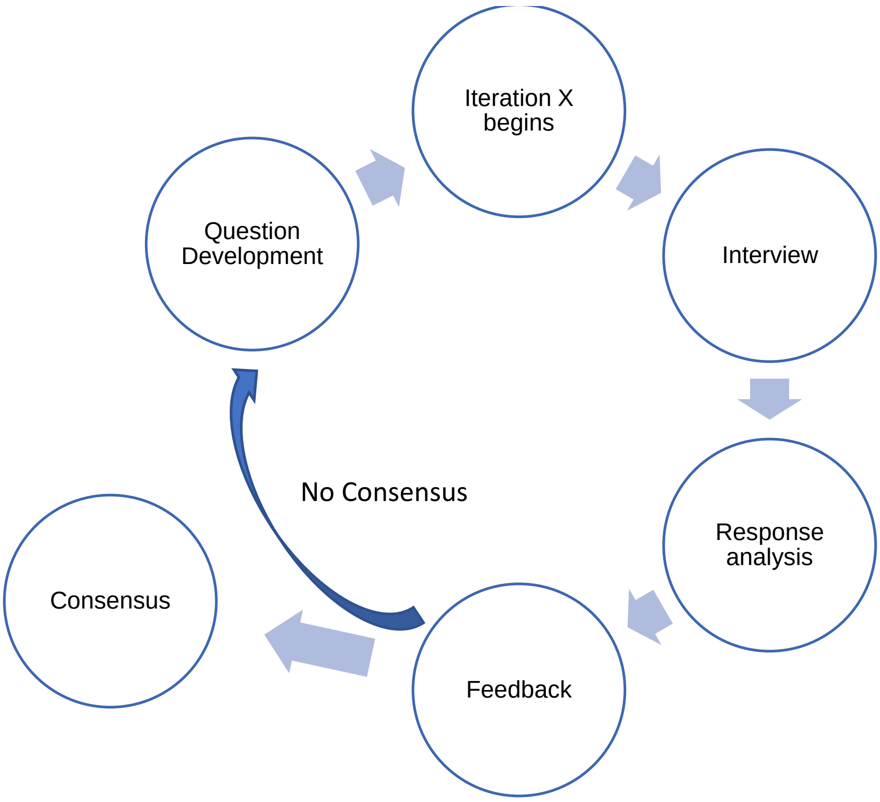

Figure 2: A simplified graphical representation of the process found in the Delphi Technique.

When using the Delphi method there are a number of things to take into consideration. Firstly, to ensure the validity of the study, there should be at least three iterations of the questionnaires (Thangaratinum & Redman, 2005), however, more can be used if after three iterations consensus has not been reached. It must be noted that an excessive number of iterations may lead to participant fatigue and disinterest, and so the number of iterations should be kept to a minimum (Walker & Selfe, 1996).

Verhagen and colleagues (1998) define consensus as "general agreement of a substantial majority." As the field of Botany is a diverse field, the opinions on what is considered important will likely be equally varied and as a result it is unlikely that there will ever be 100% consensus. It must also be noted that as variants of this methodology have evolved, it has been highlighted that reasons for dissensus are often as useful as reasons for consensus and should not be overlooked (Toppinen, *et al,* 2017). Similarly, Gordon (2009) indicates that the value of a Delphi study does not lie in statistical results but rather in the ideas that it generates and insights it provides. Furthermore, other authors suggest that a Delphi process can be stopped if opinions remain stable across rounds (von der Gracht, 2012). For the purposes of this study, consensus was considered as having more than 75% agreement, similarly to a study done by Van der Linde, *et al,* (2005). Percent agreement will be determined based on how many participants share the same/similar view on each particular area within the entire group of participants, if this falls above 75% of the participants it will be considered as having reached a consensus.

The second item in need of consideration regards the participants of the study. In terms of sample size, Linstone (1978) suggests that the method requires a minimum of 7 participants, however other researchers seem to suggest the sample size depends on the goals of the study and the availability of participants (Thangaratinum & Redman, 2005, Skulmoski, 2007, Kezar & Maxey, 2014; Sitlington & Coetzer, 2015; Davidson, 2017). As the Delphi Technique requires the use of a group of experts to participate in the study, the sampling method used for this study is a purposeful sample. Members of the Department of Plant and Soil Sciences at the University of Pretoria were asked to participate. Individuals from 14 other universities around South Africa were contacted using contact details found on their respective departmental webpages, and then asked to participate. As this study used participants from across the country, interviews and follow up questionnaires were conducted over an online forum.

There is the concern of bias with regards to researchers being acquainted with the participants of the study. For this study, researcher acquaintance with participants specifically from the University of Pretoria is unavoidable. However, this can be mediated both by the use of a large sample size as well as the anonymity of participants. The anonymity of participants is a cardinal feature of the Delphi Technique and requires that participants remain anonymous to each other at all points of the study (Thangaratinum & Redman, 2005, Van der Linde, *et al,* 2005). Due to this study using interviews as a data collection method, complete anonymity between the main researcher and the participants was very difficult to achieve. However, by allocating numerical labels to participants, anonymity of participants was upheld with regard to individuals/researchers involved in peer debriefing. Furthermore, the allocation of numerical labels to participants in a large enough sample size may result in participants becoming “lost in the data”, so that to even the main researcher, specific responses are no longer connected with individual participants.

1.3.6 Participant Sample

The sample group was a purposefully chosen sample group of 23 individuals from 11 universities across South Africa. My sample group was defined as "Plant Scientists/Botanists who currently lecture plant science or have lectured plant science courses throughout their careers." Individuals that fell within this definition were contacted using the contact details found on their respective departmental webpages and asked to participate. Participants were included in the study based on their willingness to participate. Please refer to "C. Participant Sample" in the General Introduction of this study for more information regarding the sample group.

1.3.7 Data Collection

The method of data collection took place following the criteria of the Delphi method as discussed above, and as a result took place in different phases. After the workshop presented to UP Department of Plant and Soil Sciences staff by Prof G. Uno, a questionnaire was sent out to a number of the staff within the department asking for their opinion on certain elements of the curriculum reform for the first-year course. These responses, coupled with the learning objectives discussed in the "Vision and Change: A call to action" report (AAAS, 2011) were used to form the open-ended questions used in the first iteration.

The second phase of the study consisted of a cycle of iterations. The initial interviews involved a structured interview using an electronic platform. The decision to conduct online interviews was made as a result of the onset of the Covid-19 pandemic, however, it also dramatically expanded the sample of the study. The use of online platforms to conduct research and collect data has become increasingly popular over recent years (Hawkins, 2018) and has a number of advantages over traditional face-to-face interviews. One of the main advantages is the reduction of geographical barriers, making data collection not only more affordable but also more time efficient (Walker, 2013; Hawkins, 2018). Fritz & Vandermause (2017) discuss how the ability to schedule interviews can increase an individual's willingness to participate in a study, a massive advantage for studies requiring large sample groups. There are, of course, disadvantages to online interviews such as slow connectivity and other technological malfunctions that may hinder data collection (Hawkins, 2018). During these interviews, participants were asked to respond to the open-ended questions (Appendix B) prepared in the previous phase.

Interviews were conducted by the main researcher, recorded (with permission from the participant) and transcribed for analysis using the transcription software, Otter.ai. (Otter.ai.com) As the aim of the interviews is to collect rich and informative data, the interviews had no time limit, the duration of the interview was subject to the depth of each of the participants' answers. The use of interviews for this iteration is purposeful and has the aim of collecting as much in-depth data as possible, allowing participants to expand on their responses to the questions as much as possible without placing a high burden on the participant. Once transcribed, each participant was sent copies of their transcribed interviews for verification and allowed to make amendments where needed. The responses were then condensed and thematically analysed.

A second iteration then took place, with more specific questions (Appendix C) that were based on the condensed responses to the first iteration. This iteration was conducted in the form of a short online questionnaire, using multiple choice questions and Likert scale questions, in an attempt to limit respondent fatigue. The participants were given a brief summary of the initial results from the first iteration before they were asked to complete the questionnaire for the second iteration. Of the 23 participants that had initially agreed to participate, 21 (91%) responded to the questionnaire. Data was quantitively analysed using Qualtrics.

1.3.8 Data analysis

Once the interviews were completed, the recordings were transcribed using the online transcription software "Otter.ai". The transcriptions were edited into intelligent transcriptions by the researcher. Intelligent transcriptions are transcriptions where filler words and pauses have been removed and grammar has been corrected (Delve, n.d.). Once edited, the transcriptions were summarised into a more workable format. The researcher summarised the participants answers into short sentences that answered the question being asked or added value to the discussion around the question. The removal of sections of text that were not answering the questions as well as long examples made the text easier to analyse. Once summarised, the data were thematically analysed. The data were analysed over two cycles using inductive coding. Inductive coding involves prescribing codes to the raw data and modifying these throughout the process (Delve, n.d.) The first cycle of coding used structural coding to break the transcriptions into specific sections which would then be analysed further. For the purpose of this study, each question was considered to be a different category.

The second cycle of coding used open coding to link a label or a description to a numerical value. Each category identified in the initial cycle of coding was coded independently during the second cycle of coding, i.e., the codes and their descriptions for one question may not coincide or overlap with the codes and descriptions assigned to another question. Once the coding process were completed, the data was analysed both qualitatively and quantitatively.

1.3.9 Validity and Reliability

In qualitative research, validity means that the researcher checks for the accuracy of the findings by employing certain procedures (Gibbs, 2007 in Creswell, 2014). Using the Delphi Technique as a data collection method in itself ensures validity as the cycles of iterations are based on consistent participation from the sample of contributors as well as anonymity of the participants which allows for the voicing of honest opinions, comments and thoughts (Day & Bobeva, 2005).

Reliability in qualitative research indicates that the researcher’s approach is consistent across different researchers and different projects (Gibbs, 2007 in Creswell, 2014). The reliability of the research was ensured in a number of ways. Firstly, all interviews were semi-structured, consisting of the same group of questions for each participant. Interviews were recorded and kept, and transcriptions thereof were checked to ensure that all information obtained from them is transcribed correctly.

Throughout the course of the study, the decisions and actions of the main researcher were validated by undergoing “peer debriefing,” which Janesick (2015) describes as follows: “Peer debriefing allows a qualified peer researcher to review and assess transcripts, emerging and final categories from those transcripts, and the final themes or findings of a given study. Also, a peer may review selected site documents, observational notes, and possibly other written work of the researcher. This peer may assess whether or not a researcher has missed a key point, overemphasized a minor one, or repeated one or more points. In addition, a peer acts as a sort of critical detective and is similar to an auditor auditing the ledgers of finance.”

Peer debriefing has been said to help ensure both validity and reliability of a study (Janesick, 2015). A large sample size can also help verify the validity and the reliability of a studies results (Skulmoski, 2007). As mentioned previously, bias between the researcher and participants they are acquainted with is nearly impossible to eliminate, however a large sample size and the use of a numerical labelling system for the participants can help with this.

1.3.10 Ethics

Ethical clearance to perform the study was obtained from the University of Pretoria Ethics Committee (NAS093/2020) before the commencement of the study. Prior to the collection of data, permission from the lecturers was obtained allowing their opinion to be used in the study in the form of a signed consent form (Appendix A). Participation in the study was voluntary and participants could leave the study at any time. The participants and the universities they are employed at remain anonymous when reporting the data.

1.4 Results and Discussion

The first round of questions took place in the form of interviews. The participants were given the opportunity to prepare for the interview as the questions were sent to them before the time. The following includes the first round of questions and responses:

1.4.1 The State of Plant Sciences in South African Universities

Before I set out to identify how I could reform the introductory plant science curriculum, I wanted to explore the state of Plant sciences in South African universities. I did this using the first three questions of the interviews (Appendix B).

1.4.1.1 Plant Blindness in University Students

Plant awareness disparity, originally coined by James Wandersee and Elisabeth Schussler in 1998, is defined as ""(a) the inability to see or notice the plants in one's environment; (b) the inability to recognise the importance of plants in the biosphere, and in human affairs; (c) the inability to appreciate the aesthetic and unique biological features of the life forms belonging to the Plant Kingdom; and (d) the misguided, anthropocentric ranking of plants as inferior to animals, leading to the erroneous conclusion that they are unworthy of human consideration." (Wandersee & Schussler, 2001). Question one probed whether or not participants believed plant blindness (newly termed Plant Awareness Disparity and will be referred to from here on as such) is an issue in their institution. Consensus was reached for this question with 87% (20 of 23 participants) agreeing that plant awareness disparity does in fact occur and is an issue in their institution

When participants were asked to elaborate on their answers, the following 5 themes came to light most frequently:

1. Lack of appreciation of complexity/understanding of importance of plants to life

   Participants felt that the complexity of plant structure and anatomy and the intricacy of their physiology was not appreciated by students or the general public. The importance with regards to their role in agriculture, climate change and general contribution to society is not well grasped. This very broad statement encompasses many of the "symptoms" of plant awareness disparity that are listed by Wandersee & Schussler (2001). These include a) inattention to plants that form part of one's daily life, b) assuming that plants are merely the stage on which animal life is portrayed, c) misunderstanding what is required for plants to live, d) failing to see the importance of plants in daily life, e) neglecting to notice the differences between plant and animal activity f) lacking personal experience and connection with plants in one's geographic area, g) misunderstanding basic plant science concepts involving local plant communities and lastly h) being insensitive or indifferent to the uniqueness of plants and their aesthetic qualities (Wandersee & Schussler, 2001).

2. Lack of enthusiasm towards/enrolment in plant science degrees

   Participants indicated there is a lack of interest in studying Plant Science related degrees when compared to other degrees. This will be discussed further in a later section, but is also a well recorded as a consequence of plant awareness disparity (Wandersee & Schussler, 2001). Although this may overlap with point 4; "Plant Awareness Disparity is an issue in society as a whole", this section speaks specifically to students avoiding plant science modules where possible as well as the low enrolment numbers in plant focused degrees.

3. Less interest in plants than in animals

   Participants indicated that they believe there is a general increased interest in animals when compared to plants, across both students and the population.

The general idea amongst the public that plants are more interesting than animals has been well documented (Allen, 2003; Balas & Momsen, 2014; Balding & Williams, 2016; Flannery, 1991; Schussler & Olzack, 2008; Schussler, *et al,* 2010; Strgar, 2007; Strgar, 2008; Wandersee & Schussler, 1999; Wandersee & Schussler, 2001) and also falls into the commonly listed "symptoms" of plant awareness disparity (Wandersee & Schussler, 2001).

4. Plant Awareness Disparity is an issue in society as a whole

   Participants indicated that the issue of plant awareness disparity and the general disinterest in plants is not limited to students in our universities but also plagues the general public and those in primary and secondary educational spheres. Plant awareness disparity was originally attributed to animal focused teaching in schools (Abrie, 2015; Schussler & Olzack, 2008 & Wandersee & Schussler, 2001) and lack of plant-based content in biology textbooks (Balas & Momsen, 2014; Uno, 1994; Hershey, 1992).

5. Lack of marketing compared to other well-known careers/ lack of understanding with regards to what jobs are available in the field.

   Participants indicated that career opportunities in plant sciences are not as well marketed when compared to commonly pursued careers such as medicine, law and economics, suggesting that students are often unaware of the need for individuals with a plant science degree.

The top three reasons given by participants explaining why they thought plant awareness disparity was an issue in their institutions coincide with the definition of plant awareness disparity (Wandersee and Schussler, 2001). The fourth most commonly given answer; "issue in society as a whole" also aligns with previous research and also tells us that the issue is far bigger than just academic institutions alone but rather it is a societal issue that will need to be dealt with on more than one level.

1.4.1.2 Enrolment Numbers for plant science/Botany Degrees and Courses

Question two probed whether or not the department of the respondent had issues with students enrolling for their plant science degrees. Seventy percent of participants mentioned that they did believe enrolment was an issue. Although this does not meet the previously stated percentage that indicates consensus, it is the overwhelming majority.

The top 5 descriptions coded when asked to elaborate were as follows:

1. Students don't understand importance of plants/importance of research in the field.
2. Students don't realise career opportunities or application of knowledge.

These first two statements can be labelled as a direct consequence of plant awareness disparity and align with what the participants answers to the question regarding plant awareness disparity being an issue.

3. Post graduate students are better than undergraduate students/ certain areas are better than others.

   Participants suggested that there is generally a larger interest in postgraduate students, as well as a larger number of postgraduate enrolments for plant sciences than undergraduate enrolments for plant sciences.

   "I think the, the problem is not really that much in our senior modules, you know, if you look at third years, and then going on to honors and postgraduate, because I think by that stage, the students have really had a chance to engage with plant science, and then also especially see post grads, they've made up their minds in terms of what direction they want to go to, I think a major problem lies with lies with the first year students and the second year students, because if you take a look at the enrollment of first years coming into university, and looking at what degree they opt to register for BSc plant science, is numbers are very low." – Respondent 11.

Although this has a positive impact on the department, it is often undergraduate numbers that dictate the funding for departments as well if a department should or shouldn't be merged with other, stronger departments.

4. Lack of exposure to plant sciences/ interest in plant sciences.

   Plant sciences is not a large section of the secondary education syllabus (Abrie, 2015). Furthermore, teachers are often inexperienced in teaching this subject matter and do not teach it to its full potential. The concept of animal focus teaching leading to a decreased interest and understanding in plants is not a new one (Schussler & Olzack, 2008 & Wandersee & Schussler, 2001). Furthermore, other than the use of medicinal plants, plants rarely feature on a cultural level when compared to the roles of animals (Lindemann-Matthies, 2005 & Strgar, 2008).

5. Dual majors are an issue/ compulsory courses skew number.

   Participants indicated that dual majors, (students who complete all the requirements in two different academic majors) skew enrolment numbers for plant science courses and also for degree completions. They indicated that students doing dual majors with plant science courses usually graduate under a different department despite having plant science courses. Despite this, participants mentioned that dual majors can have a positive effect on the number of students in plant sciences courses.
   Furthermore, participants indicated that compulsory courses, such as BOT 161, skew the plant sciences enrolment numbers, suggesting that there is a large enrolment for plant science courses until on a third-year level when numbers drop drastically, especially in comparison to zoology courses.

The difficulties around low enrolment for plant science degrees is not new and is well documented. Tertiary institutions in the United Kingdom have removed Plant science degrees from their educational programmes due to lack of enrolment (Drea, 2011; Wandersee and Schussler, 1999). Rhodes University, University of the Free State and the University of Zululand are the only universities with a free-standing department of

Botany/ Plant Sciences of the universities whose staff participated in this study. Most commonly, departments are merged with soil science, biotechnology or zoology. Although low course enrolment and curriculum appear to be different issues, low enrolment could be helped by presenting an updated plant science curriculum, which sparks student interest.

1.4.1.3 General Approach to Plant Science Curriculum

Question three asked whether or not participants thought that a narrower or a broader approach should be used when approaching the new curriculum of the course. A broader approach referred to the curriculum consisting of small but diverse sections of knowledge from several different disciplines within the field of plant sciences. A narrow approach referred to the curriculum consisting of one or two large sections of knowledge that focuses on one or two core areas of plant science in great detail. Fifty-seven percent of the participants voted for a broader approach, with the top reasons including:

1. Good opportunities to expose the students to different fields/ opportunities/ relevance.
2. Broad approach could help with exposure.
3. Good opportunity to spark interest.
4. Gives broad basis for foundational knowledge that is not in-depth but aimed at a wider audience.

Co-incidentally, all of the above-mentioned reasons apart from the fourth reason would contribute to mitigating plant awareness disparity as well as combat some of the major reasons that participants believed plant science degrees had low enrolment numbers.

Thirty percent of participants mentioned that a mixture of both a broad and a narrow approach should be used, agreeing that the broad approach can help with exposure and interest but also saying that students require the fundamental basics from the narrow. The remaining 3% believed that a narrow approach should be used, mentioning that students require a strong foundation which the narrow approach will give.

Although this does not meet the earlier discussed percentage for consensus of 75% we can gain valuable insight from this, especially in conjunction with the previously mentioned sections of "Plant Blindness in University Students" and "Enrolment Numbers for Plant Science/Botany Degrees and Courses".

1.4.1.4 The Importance of Hands-on Practical Tasks

The participants were asked whether or not they believed that hands on practical sessions are important in an introductory plant sciences course. 100% of participants responded yes to this question. Participants gave reasons including the need to spark interest in the plant sciences but also help expose students to their interests and the opportunities in the field of plant sciences. This was the only question where 100% consensus was reached during both the first and second iteration of this study.

The recurring themes of lack of interest and lack of exposure to plant sciences that were found within all of the questions aimed at determining the state of plant sciences in South Africa suggest that if the department were wanting to try make a change within our plant science departments that this could potentially be a good place to start. Furthermore, it backs up the idea that these issues run far deeper than just in students in tertiary institutions but rather that they are issues found in the greater part of society as a whole.

1.4.2 Plant Science Curriculum

After gaining more insight into the state of plant science in South Africa in general, I set out to answer my first research question;

What core concepts and core competencies should be included in an introductory plant science course?

1.4.2.1 Vision and Change Core Concepts

Question four (Appdendix B) probed the participant opinions regarding which of the 5 concepts (section 1.2.2) suggested by Vision and Change are most important in an introductory plant science course. They were asked to pick the two concepts that they believed where most important. Participants where asked to only select two to limit the amount of choices participants had and so helping to create consensus. There was concern that participants would deem all the concepts important (which some participants did) and this would take the results away from the main goal, of trying to determine which are most important.

The concept Evolution was the most common "first choice" by participants. Two participants indicated that this can be quite a controversial topic and should be better understood. This is followed by the concept Structure and Function as the most commonly chosen "second choice" (Figure 3). Here it was noted by eight participants that the structure and functioning of plants should be considered to be the very foundation of plant sciences. Neither of these reach the 75% for consensus, however they show a clear majority. Overall, there were three core concepts that stood out; being chosen more often for the top two most important concepts than the other two of the five core concepts, these being evolution, structure and function and pathways and transformations of energy and matter.

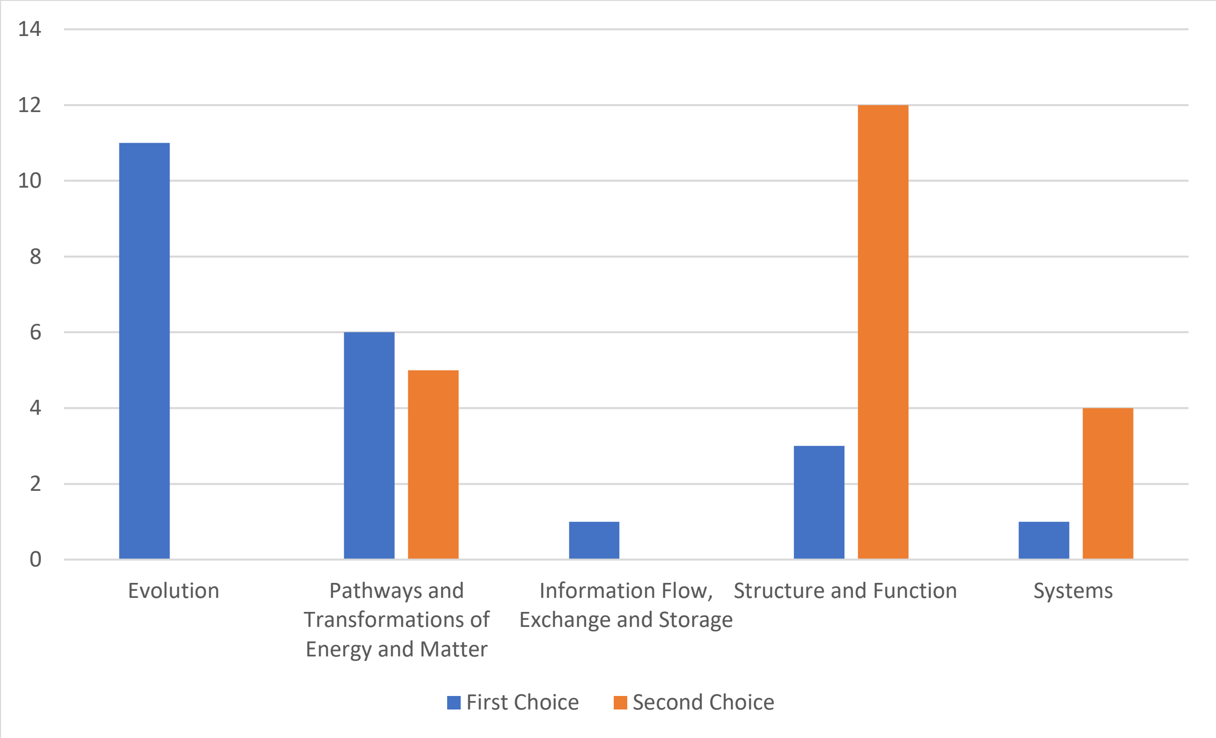

Figure 3: Graphical representation of participants choices for two most important concepts (n = 23).

Several participants had comments regarding this that must be noted. Firstly, six participants mentioned that repetition should be avoided, particularly when it comes to concepts that have been dealt with previously in other courses. It was also indicated that the new curriculum needs to pique students' interest and capture their attention as best as it possibly can, tying in with the results of the previous section. Eight of the participants indicated that although they had chosen the two most important concepts as they had been requested to do, they believed that all of the concepts where important in some way. Furthermore, it was discussed that teaching students the application of the theory work was vitally important and should be taken into consideration.

1.4.2.2 Vision and Change Core Competencies

Similarly, to question four above, participants were asked to pick the top two competencies which they believed were most important or most valuable to include in an introductory plant science course. The results are as follows:

The most commonly chosen "first choice" for most important is the Process of Science, which relates back to the importance of hands-on practical sessions that gained 100% consensus in the previous section. The most commonly chosen "second choice" was understanding and interpreting data, which again aligns with teaching students' hands-on practical skills as well as with the scientific method (Figure 4).

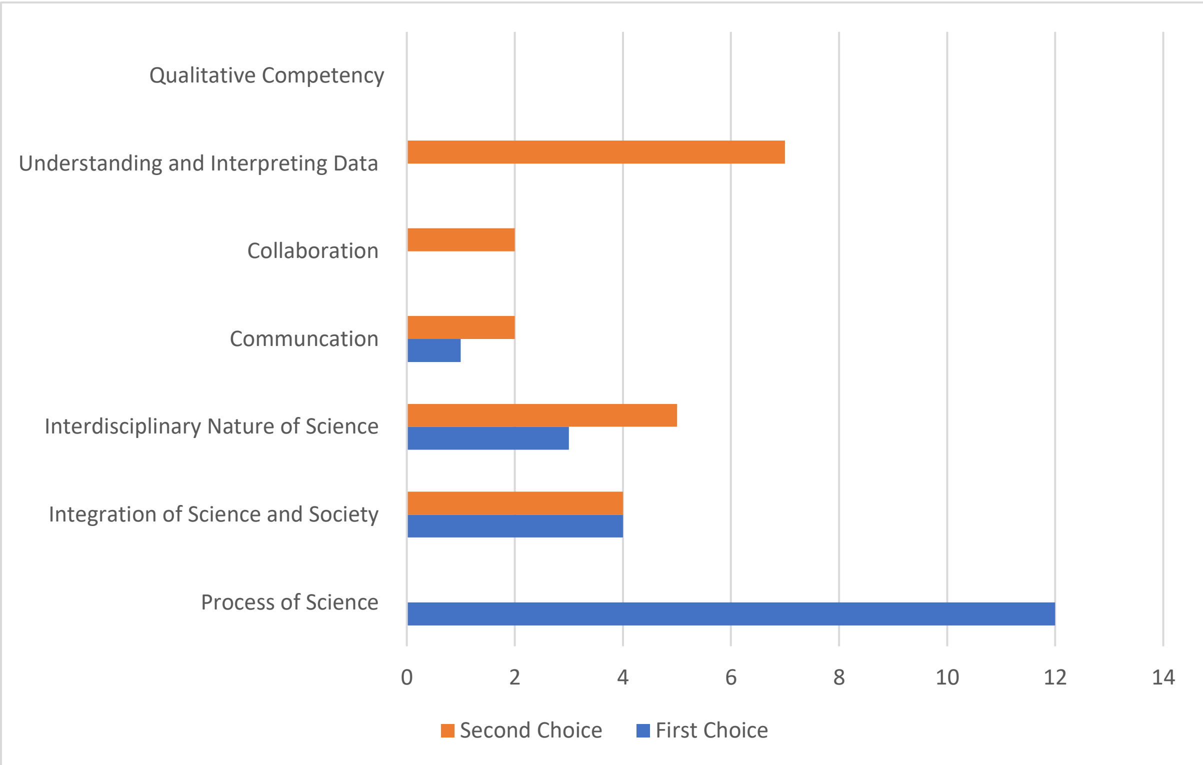

Figure 4: Graphical representation of participants choices for two most important competencies (n = 23).

Once again it was mentioned that repetition should be avoided where possible and that piquing student's interest is important, especially in areas that it can expose students to potential careers and the importance of plant sciences research. As with the core concepts, there are three core competencies that were chosen more often overall than the others competencies; process of science, integration of science and society and interdisciplinary nature of science.

1.4.2.3 Least Important Core Concepts and Competencies

The participants were asked which core concepts and competencies should be left out of a first-year plant science course, the most commonly chosen concept was “information flow, exchange and storage” which corresponds to the results of question four (section 1.4.2.1). The most commonly chosen competency was collaboration which again coincides with the results from question five. Two participants mentioned that although they didn’t think any of them should be left out in both the concepts and competencies, they mentioned that unfortunately there was not enough time in the semester to touch on all of them properly. This question was asked to help ensure the validity of the responses in questions four and five.

1.4.3 Iteration Two

Iteration two took the form of an online questionnaire. Twenty-one of the original 23 participants responded to the questionnaire (Appendix C). The questionnaire consisted of 12 questions, which were either multiple choice or rank order style questions. Data from the initial interviews suggested there was potentially a divide in how lecturers view the purpose of an introductory plant science course; whether the focus should be on sparking interest in students or in instilling basic content knowledge. In light of this, I posed this question during the online questionnaire (Appendix C). The results showed that 57.14% of participants believe that an introductory plant science course should be used to spark the interest of students rather than instil basic content. It must be noted that interest and content knowledge do not need to be mutually exclusive; it is possible to teach in such a way that you convey content knowledge and spark interest in the subject matter at the same time.

1.4.3.1 Vision and Change Core Concepts

The initial iteration asked participants to indicate which two concepts they believed to be most important for an introductory plant science course. Analysis of these data provided us with three concepts that were chosen more often than the remaining two. These being:

1. Evolution
2. Pathways and transformations of energy and matter
3. Structure and function

In order to refine this, the participants were asked during the second iteration to rank these three concepts in order of importance. All remaining 21 participants answered the question.

The results are represented graphically in figure 5. In iteration one, structure and function had the most votes overall, however the concept of evolution had the most first choice votes. Structure and function remained in the position of "most important" but was ranked so by 57% of the participants, as appose to the initial 61% of participants when looking at the overall score from iteration one. In contradiction to the initial iteration, pathways and transformations of energy and matter was now ranked as second most important with 57% of participants ranking it as second. This ranking changed by 14%, where it was tied with the topic of evolution after the initial iteration. Lastly, the topic of evolution dropped to third place with 62% of participants ranking it as least important of the three topics.

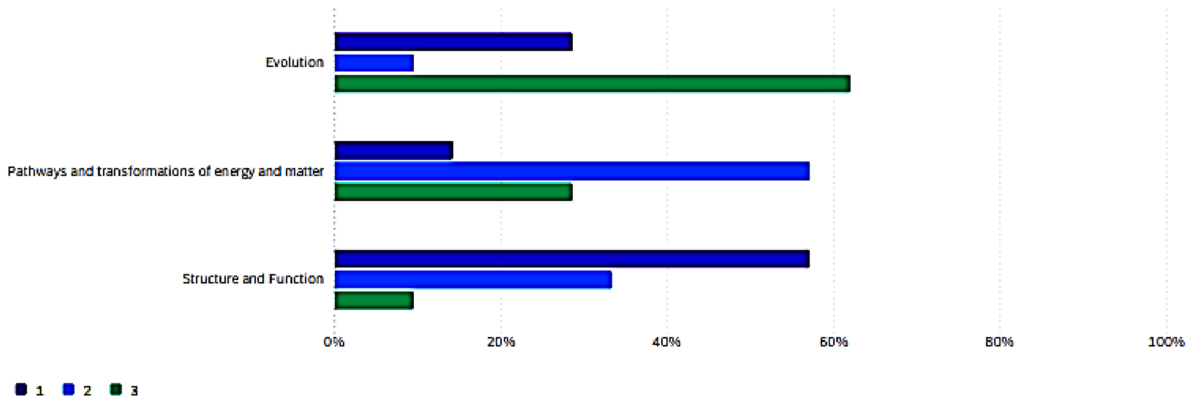

Figure 5: Ranking of top three core concepts from iteration one (n = 21).

These results give us a much clearer picture of what the participants believe to be important than the results from iteration one and although none of these reach the defined amount for consensus, they give us a much clearer idea of what the participants believe to be important and can be seen are areas of common majority or agreement. During iteration one, participants mentioned that structure and function gives a good foundation for students going further into second- and third-year plant science courses. I suspect that it is for this reason that structure and function has been chosen as most important during iteration two.

“… structure and function is a good foundation. And that's why I think it's nice for first year as well, it's a good one. The pathways and the information are essential, but that can be learned at a later stage.” – *Respondent 9*

In an attempt to reach consensus by providing more narrowed down and detailed options to choose from, the statements from the BioSkills Guide (Clemmons, *et al,* 2020) were included in the questionnaire of the second iteration for the top three competencies. These results did not yield any useful information, but rather took the participants further away from consensus and so are not discussed in further detail.

1.4.3.2 Vision and Change Core Competencies

In the initial interviews, participants were asked to identify which competencies listed in vision and change they thought were most important to include in an introductory plant science course. The results were not clear cut, however a top three did emerge:

1. Process of science
2. Interdisciplinary nature of science
3. Integration of science and society

In the online questionnaire for iteration two, participants were asked to rank these three in order of importance, the results can be seen in figure 6. It must be noted that only 16 of the 21 participants chose to respond to this question. The process of science was ranked as most important by 69% of the participants. This corresponds with the data collected during the iteration one. The link between science and society was ranked as second most important, with 50% of participants ranking it there. The interdisciplinary nature of science was ranked third by 44% of participants. This data analysis was done by Qualtrics (Qualtrics, Provo, UT), and can be seen in Appendix D.

Similar to the core concepts, the results for iteration two give us a clearer picture than the results from iteration one, however, none of them reach the defined 75% of consensus. These results do however align with the 100% consensus result which was received for the "hands-on practical" question.

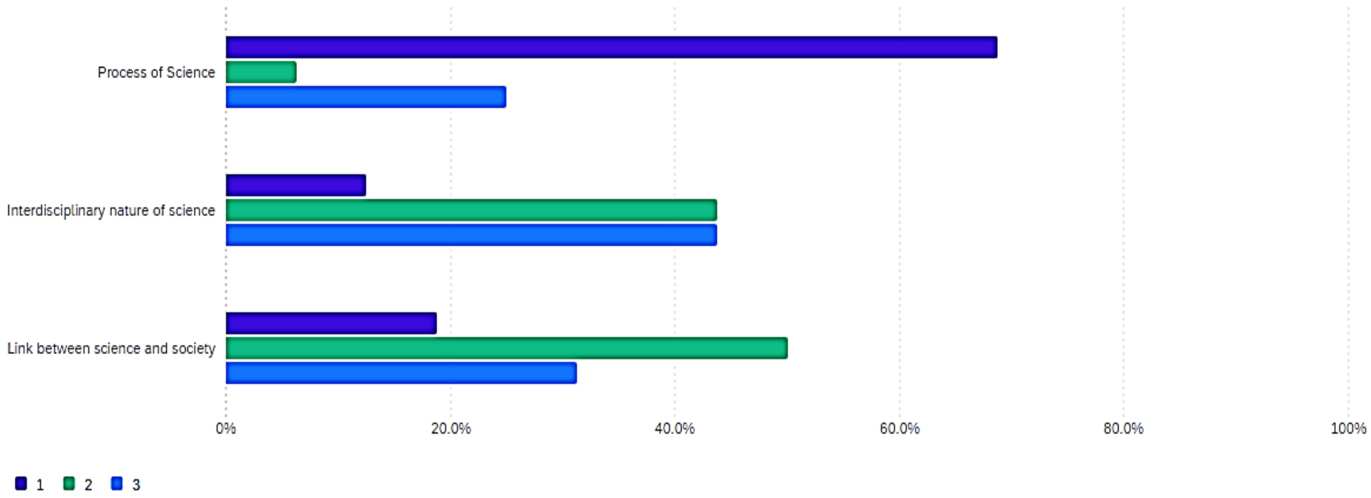

Figure 6: Ranking of top 3 competencies from iteration 1 (n = 21).

There was initially concern that there would be bias connecting what lecturers believed to be important and their area of research. A *chi*-square test was performed and indicated that there was no relationship between a participants' answers and their field of study ($p<0.05$).

1.5 Limitations of the Study

There are a number of limitations that need to be considered with regards to this study. Although the data collection methods used in this study did not require a specific sample size, I believe that a larger sample size would benefit this study with regard to reaching some kind of consensus. Secondly, the majority of the participants were employees of one of the 14 universities taking part in the study. Although the study aimed to gather the independent ideas and opinions of the participants, it must be noted that the shared common goal of the department may have influenced participants.

1.6 Conclusion

Although I did not gain consensus of opinion on anything except for the need for hands-on practical tasks, I did see an overwhelming majority of opinion with regards to what is important in an introductory plant science course. With regards to identifying which core concepts should be included in an introductory plant sciences course, the concept Structure and Function clearly has the majority vote. Similarly, with regards to the core competencies, the Process of Science has the majority vote in both the first and second iteration. Neither of these reach the defined level that indicates consensus, however, it can give us a base line to work on, even if it only involves how we approach these concepts and competencies in our classes without implementing any drastic change. This indicates that there is a lot of work that can be done in terms of refining these concepts and competencies in terms of Plant Science. It is also clear, that there is a real need to spark students interest in plant sciences as well as ensure that they are well informed regarding the importance of the field and the career opportunities that it offers.

Furthermore, I believe that the voice of industry should be heard with regards to what tertiary education institutions are including in their curriculums. Industry benefits directly from our undergraduate students, and will have their own opinions on what content and competencies they believe should be included in curricula. I think that the needs of industry should have a much greater influence on what we teach in our higher education institutions.

Finally, I believe it would be more productive if we approached similar studies with a more focused, top-down approach. To begin, I believe it would be beneficial to concentrate on a single degree within plant sciences, such as plant pathology or ecology, and dealing only with experts in that particular field would help narrow down the spectrum of results and possibly lead to achieving consensus. Starting with what each particular industry needs, we can filter down changes from final year, which will help ensure that we are not repeating information or expecting students to have previous information that is not taught in other modules. Our goal as a higher education institution should be to prepare our graduates to enter the working world with content knowledge and the skills they will need to make a meaningful contribution to society. If we are out of touch with what industry requires from its employees, we will not be able to fully prepare our students for life after graduation. Approaching a panel of experts with this information may help participants to make more informed decisions and could lead to achieving consensus.

2. Chapter 2 – Barriers to Change

2.1 Introduction

Driven by the national calls for education reform and a growing awareness of how technology and industry are changing what graduate students require to be successful, we recognize that there is a need for change, however we also recognise that change is rarely easy and seldom takes place without some kind of resistance or opposition. Opposition to change can make or break the implementation of any initiative (Pardo de Val & Martínez Fuentes, 2003), and so it is important that we identify what these potential barriers are if we are to help mitigate them and successfully implement change.

This chapter has four main parts; a literature review, a methodology section, results and discussion and a conclusion and will focus on my investigation of the potential barriers that could arise throughout the process of implementing curricular changes in an introductory plant science course, specifically aiming to answer the second research question for this dissertation:

1. What barriers could arise throughout the process of implementing curricular changes in an introductory plant science course?

It has been well documented that any kind of academic change is difficult, and this is no different for undergraduate biology courses (Brownell and Tanner, 2012; Henderson, *et al,* 2011). Resistance to change, also called barriers to change, come in many shapes and sizes, however, in the most general sense have been shown to result in the failure of change initiatives. Thus, the study of these barriers is important as it can help improve success rates of projects aimed at implementing change (Pardo de Val & Martínez Fuentes, 2003).

Despite an overwhelming amount of literature suggesting there is a need for undergraduate biology reform, there is little evidence that suggests that lecturing staff are actually actively seeking to improve their teaching or their courses (Chen, 2015; Tagg, 2012).

In their paper addressing barriers to change in higher education, Brownell and Tanner (2012) eloquently posed some of the questions I had when embarking on this study; “In fact, it is somewhat perplexing that we as scientists are resistant to such change.

We are well trained in how to approach problems analytically, collect data, make interpretations, form conclusions, and then revise our experimental hypotheses and protocols accordingly. If we are experts at making evidence-based decisions in our experimental laboratories, then what forces are at play that impede us from adopting equally iterative and evidence-based approaches to teaching in our classrooms?"

2.3 Methodology

This section describes the methodologies and procedures used to investigate the potential barriers that could arise throughout the process of implementing curricular changes in a first-year plant science course. As this study followed the same methodology as Chapter 1, please refer to 1.3 Methodology to avoid repetition.

2.2 Literature Review

This literature review explores some of the existing literature that deals with barriers to change in higher education. I will discuss barriers to change on both individual and institution levels, as well as looking at change with regard to content and pedagogy.

Ansoff (1991) defines resistance as "something that influences the change process by deferring or backing off its starting, impeding or preventing its execution, and expanding its costs." Pardo de Val and Martínez Fuentes (2003), describe resistance to change as a phenomenon that affects the change process by "obstructing or hindering" its implementation in any way or "conduct that tries to keep the status quo and avoid change."

Change in any situation is difficult and rarely willingly embraced by anyone (Armstrong, 2016), however, change in an academic environment appears to be particularly difficult (Henderson, *et al,* 2011; Brownell, 2014) and despite apparent need for change to allow us to keep up with every changing technology and social environments, when it does take place, it happens very slowly (Eaton, *et al,* 2020; Armstrong, 2016). This delay in implementing change is something that is often misconstrued as direct opposition to change (Armstrong, 2016). Asking an academic to change their pedagogical approach can imply that not only were their professors and mentors not teaching effectively but also that what they have been doing in their own classes is not the best way to engage today's very diverse student population (Brownell and Tanner, 2012). Hoffer (2003) (in Armstrong (2016) states that change can cause a "crisis in self-esteem" due to the perception of our previously valuable skills being deemed useless in a new situation. Furthermore, universities have been described as “non-hierarchical networks that resist strong top-down control and seek meaningful justifications for changes” (Annala, 2021). Taking this into consideration, it is not hard to see why most higher education institutions battle to implement lasting change (Armstrong, 2016).

Tagg (2012) states that despite the overwhelming evidence in the form of both policy documents and research publications suggesting reforms of our education systems are long overdue and a number of funding opportunities in place to motivate change, it is only being spearheaded by a small number of university staff that are reaching small groups of their colleagues. The result of this is that the academic community is making insufficient progress in reform (Eaton, *et al,* 2020). Although this study is specific to the United States, South Africa has similar issues.

There is literature that deals with the barriers to change both in education and other organizations (Grama and Todericiu, 2016; Armstrong, 2016; Brownell and Tanner, 2012), however, not a lot of this literature deals with successful implementation of changes (Cooper, 2017). Using other organisations as a model for higher education systems helps us to identify potential barriers to change, and it has been shown that higher education is generally similar to other organisations in this regard (Armstrong, 2016). Resistance to change has been blamed for the failure of implementation of numerous initiatives (Pardo de Val and Martínez Fuentes, 2003). Regardless of the organization, it is therefore crucial that we gain a good understanding of resistance to change if we are to make progress in removing them, providing sufficient support to those who need it and moving forward with successful reform (Cooper, 2017; Armstrong, 2016; Pardo de Val and Martínez Fuentes, 2003).

Literature dealing with resistance to change most often cites lack of training, time and incentives as barriers to change in terms of education and academic staff in higher education institutions (Brownell and Tanner, 2012; Cooper, 2017). The result of this is that the bulk of both research and reform efforts focus on these three barriers (Brownell and Tanner, 2012; Henderson *et al,* 2011; AAAS, 2011) despite there being other understudied and unidentified barriers that hold equal value as these, such a professional identity (Brownell and Tanner, 2012). Cooper (2017) suggests that insufficient understanding regarding the planned change, lack of support for academic staff and differing values and ideas of education and teaching are also practical barriers to curriculum change. I will now take an in-depth look at some of the more commonly suggested reasons that change in higher education is resisted, with regard to individuals.

2.2.1 Lack of Training

It has been noted that many academic staff feel under-equipped to change their pedagogy (Brownell and Tanner, 2012). There is, however, no policy that requires lecturers to undergo formal pedagogical training (Brownell and Tanner, 2012). In South Africa specifically, lecturing positions require candidates to have the minimum of a master's degree in the area they wish to lecture, with some universities requiring a doctoral degree (UNISA, n.d). Formal teaching qualifications are rare in academic staff (Cooper, 2017) and it has been highlighted that there is a need for staff development/training in this area (AAAS, 2011; Cooper, 2017). Most training happens in the form of workshops, which usually have a positive effect on attendees, however, when they return to their institutions they are met with resistance from their colleagues (Brownell and Tanner, 2012). These workshops are usually short events, and although a wealth of knowledge can be passed across during a well-presented workshop, research has shown that long-lasting change is an ongoing process (Brownell and Tanner, 2012). Furthermore, training alone has been shown unlikely to facilitate lasting pedagogical change (Brownell and Tanner, 2012).

2.2.2 Lack of Incentives

The majority of research on barriers to change in academia originates from research intensive universities where performance criteria is skewed towards research output and not teaching (Kenny, 2017; Brownell and Tanner, 2012). This influences where academic staff choose to spend what flexible time they do have; research suggests that staff interested in teaching will spend their time on teaching related activities, while those who are not will spend it on research (Papadopoulos, 2017). Similarly, the reputation of an institution is based on their research, the amount of research an institution produces is much easier to quantify and measure than how successful a person's teaching is, and so is universally recognised as an indicator for tertiary institutions (Armstrong, 2016). Changing teaching strategies or curriculum requires continuity and commitment for successful implementation but this is rarely the case as research demands on time sometimes interferes with the ability of teaching staff to spend time on teaching activities.

2.2.3 Professional Identity

One of the more understudied barriers to change was brought to light by Brownell and Tanner (2012) and is called "professional identity". Brownell and Tanner (2012) define professional identity as how scientists "view themselves and their work in the context of their discipline and how they define their professional status". A professional identity is not unlike a personal identity; however, it falls within the context of a professional discipline and impacts our decision-making capability and actions within that context (Brownell and Tanner, 2012). The development of a professional identity is closely related to peer review and acceptance (Brownell and Tanner, 2012), the general idea that acceptance by your peers plays an important role in your professional identity and this is influenced by the culture of the workplace and what is deemed important. Academics usually consider themselves to be experts in their fields and often their focus is on their research and publications and not on teaching which can be detrimental to their students (Rushin, *et al,* 1997). This coincides to the time constraints that academic staff face and will be discussed in section 2.2.4 of this chapter.

This could relate both to professional identity; academic staff seeing themselves as researchers first and teachers second, or the lack of reward that may come in the form of less recognition for teaching than for research. It is imperative that we understand the role that academics have to play in curriculum redesign, because of the importance of curriculum in and its impacts on future generations (Annala, 2021). A study by Brøgger (2014) found that academics play an active role in curriculum redesign. Mathieson (2012) showed the importance of the role that academics play as agents of change in their research involving the merging of two South African universities. Similarly, Annala (2021) identified a number of key groups within academic staff regarding their role in curriculum redesign. The groups ranged from those who saw the value in education and took an interest and responsibility in curriculum change (progressive agency) to those who did not see the benefit of curriculum change or see it as part of an academic's work (oppositional agency). In addition other groups included academics who wanted to maintain disciplinary boundaries (territorial agency), those who saw themselves as mediators between various groups involved in curriculum change (bridge-building agency), others who sought to avoid conflict and undertook curriculum design as part of an academic's work (accommodating agency) and lastly, those who saw the value in curriculum change but felt they had no power to influence or execute change (powerless agency) (Annala, 2021).

2.2.4 Time Constraints

As previously stated, most training of academic staff happens in the form of workshops, which are short events hosted over one or a few days (Brownell and Tanner, 2012). Academic staff who are pressed for time, juggling responsibilities such as research, classes and students will often not have the extra time available to attend these workshops, especially if they do not see teaching as part of their professional identity or if they are not offered some kind of incentive to take part. Apart from taking time out to attend training/ staff development programs, there is often not enough time to complete the work that is needed to properly and fully implement a new curriculum (Cooper, 2017). Research shows that workload models used at universities underestimate the time needed for quality teaching and the associated administrative tasks. (Cooper, 2017; Papadopoulos, 2017). It is imperative that we acknowledge the amount of work that goes into curriculum reform, if we are to offer staff sufficient and effective support and ensure that the new curriculum is understood and implemented effectively (Cooper, 2017).

2.2.5 Institutional Considerations

An older study by Pardo de Val and Martínez Fuentes (2003) identified sources of resistance to change from an organizational perspective. They identified three groups of sources of resistance in the formulation stage and two groups of sources of resistance in the implementation stage. In the formulation stage, the first barrier to change is in the form of skewed perception; this group is characterised by denial of the need to change and the accompanying information, communication problems and lack of forward planning (Pardo de Val and Martínez Fuentes, 2003). Good communication and the implementation of information strategies has proven to lead to more successful change process (Christensen, 2014). The second group of barriers is low motivation to change; this group is characterised by concern over the cost of change, concern over past failures and contrasting interests and values amongst employees (Pardo de Val and Martínez Fuentes, 2003), a problem that can be mostly solved by communication from those initiating the change process (Christensen, 2014). The final group of formulation stage resistance is called “lack of creative response to change" and is characterised by environmental changes that are too fast and complex to allow for well throughout responses, the idea that obstacles are unavoidable and a lack of commitment to change (Pardo de Val and Martínez Fuentes, 2003). The final barrier to the implementation of change is political and cultural stalemates; characterised by departmental politics, deep rooted disagreement and differing opinions, emotional decision making and unawareness of the social context (Pardo de Val and Martínez Fuentes, 2003). The final group in the implementation of change stage is a group of miscellaneous items including, leadership inaction, longstanding routines, inability to make decisions, lack of capability to implement change and cynicism (Pardo de Val and Martínez Fuentes, 2003).

2.4 Results

This study set out to explore what barriers, according to experts, could arise during the process of implementing curricular changes.

Thematic analysis of the data pertaining to the question addressing the barriers to change revealed 14 descriptive codes, which were then grouped into 5 categories based on their similarities and labelled with an umbrella term to describe them (Table 2). Each of these categories is discussed below.

Table 2: Table summarising the 5 categories found during thematic analysis of the question pertaining to the barriers to change (question 1).

Category Label	**Description**	**# of descriptive codes in category**
Staff	Barriers posed as a result of members of staff	6
Institution	Barriers posed as a result of the institution	3
Students	Barriers posed as a result of students in the course	2
Curriculum	Barriers posed as a result of the curriculum	2
No barriers	No barriers can be expected	1

2.4.1 Category 1: Staff

The first and largest category, “staff”, refers to barriers that may arise as a result of staff. In this context, “staff” refers to members of a department that are either involved with the course in question or involved in discussions regarding the implementation of change within the course. Within this category there are six descriptive codes (Table 3). Each descriptive code represents an umbrella term that was created during thematic analysis of the data.

Table 3: Table showing the six descriptive codes found within the category "staff" and the number of responses in each descriptive code.

Descriptive Code	**Responses in Descriptive Code**
1. Time restraints	10
2. No change necessary	9
3. Direction of change	8
4. Resistance to change	7
5. Aware of need	5
6. Lack of results	2

Descriptive code one, "time restraints", received the most responses from participants. This descriptive code was the biggest source of concern for participants where they indicated that academic staff are hard pressed for time under normal circumstances, never mind the circumstances of being asked to continue their normal teaching and research responsibilities in addition to preparing completely new content for a course.

"I think a lot of my next answers all revolve around time. So, I think a lot of lecturers are obviously swamped, trying to balance research and teaching. And then of course, go try to be a normal human being with friends and family. So, it could be a daunting task to change all of your lectures all of a sudden. So, I think time is going to be a big issue. A lot of people are very set their ways and have been giving the same slides for maybe a decade, I don't know. So, but also, at the same time, I think, a lot of lecturers will be very well aware that there's time for change. And it might even be refreshing for them to start sharing some of the other knowledge, they definitely have." – Respondent 2

"To be honest, I think, the amount of work that would be involved, that is going to be a barrier, because most of the academic staff are already overloaded." Respondent 4

“So, I think that the first barrier is getting the work done, , so convincing lecturers to do the extra work of redesigning the content…” – Respondent 7

“And then, because if you change a curriculum, it means someone has to put in the work. And some will have to do a lot of extra work. So that might make it difficult to incorporate the change.” – Respondent 19

Descriptive code two, “no change necessary” has the second largest number of participant responses in the category. This code describes participant responses that indicate a general resistance to change, largely related to the idea that change is not necessary, due to the belief that the course is working well enough as it currently stands.

“So, I think there'll be a little bit of headway from staff members who have been involved in the course, and think that it's working perfectly adequately. There will also maybe be sort of kickback from staff members who want it to change because they think it isn't adequate, but they dislike the direction of change.” – Respondent 1

“…arguments might come up where, where, people might say that, you know, that the old curriculum is a tried and tested method, you know, we know exactly where the weak points are, we know how it works. It works. Okay, and with the new one. They don't really know if it includes enough information, you know, does it actually help the students later on.” – Respondent 6

“Personally, I think a lot of times, it's actually a personal thing, that people are reluctant to change. And I think, because they've been doing things for many years, they don't really want to change.” – Respondent 13

The quotes above indicate a negative perspective on change in general, the suggestion being that staff don’t want to change or don’t believe that change is necessary and this being one of the major barriers that could be faced when trying to implement a new curriculum. There was one participant that was very specific in their opinions regarding changing the curriculum. This participant said:

“I think that the drive to change the classical scientific programmes are absolutely unnecessary. At higher levels it is appropriate to be more aware of current trends, but not at first year level. The basic forms and functions within the plant

kingdom have not changed dramatically within the last 1000 years." – Respondent 21.

The participant continued by saying:

"But I agree with you 100%, that examples have to come from the South African context. If it does not come from the South African context, you lose the interest of the students immediately… In that sense, if that is the goal, then I'm 100% forward to make it applicable to our country and to a region very, very specifically. And if we take [a culturally significant group of] students, for instance, the Zulu, many of them have a pretty good understanding of medicinal use of plants. And to use that as a springboard to make them aware of conservation issues, is a very good way of looking at it. And I'm not changing the curriculum. I'm just, I'm just going at it from another angle but I'm not changing the basic building blocks that they need before they can move to the next level." – Respondent 21

This particular conversation shows that it is vitally important that we are open about the kind of change we are wanting to implement and the influence that it can have on people's willingness to do so. We need to be specific when we approach people regarding our ideas towards improving curriculum.

Descriptive code three, "direction of change", is described by participants as an awareness of staff for the need to change, but coupled with a concern over the direction of change. The concerns of participants are with regards to either a loss of topics in the curriculum, often their field of research and also concern over the potential lack of access to first years resulting in the inability to represent their field of research in an interesting and enthusiastic way.

"So, I think that the major sort of opposition to that will be probably twofold staff members that don't want to change, and staff members that do want to change, but not in the way that will eventually be implemented." – Respondent 1

"But I feel if you incorporate the weaknesses of the old curriculum with, like, the advances of the new one, then then people will be more likely to open up and to understand why this is needed." – Respondent 6

"I think that's, that's the biggest barrier, I don't think there's a lot of resistance in changing and adapting and, and realizing that there needs to be transformation and change and, and redevelopment and things in your first year. But the major thing is that you need them, the basic concepts and those things and also like kind of a bit of a revision of the basic concepts that students should have." – Respondent 16

"And then for me specifically, giving up direct access to the first years of is a bit of an issue. Mm hmm. In other words, I have to trust my colleagues to represent my field. With the same passion and enthusiasm that I have, in other words, I have to trust that they are going to do the hard work to recruit students into my discipline that I would have done." – Respondent 7

Descriptive code four, "resistance to change", is described by participants as a general unwillingness to change and was most often linked to the age of the individual being described by the participant. Participants suggested that older staff members are less willing to change than younger ones, and often linked this back to descriptive code one.

"People don't like change. And they, especially if they've been at the university for a long time, I don't want to say old people, but they don't like change, and they want to continue the way they've done before." – Respondent 19

"The older or the more stuck in their ways staff might not want to change things, they would say, "no, it's been done this way for so many years. Why do we want to change it?"" – Respondent 5

"And I think, to suggest to someone that has done something for a long period of time to change, that's going to be a bit difficult, you know?" – Respondent 6

"And then maybe just people's opinions. Maybe you have a staff member that is near to retirement, and they don't feel like change? And then they can have all kinds of excuses why it should not done." – Respondent 23

Despite the various concerns from staff members regarding the potential barriers that may be faced when redesigning the curriculum of a course, it must be noted that a substantial portion of participants acknowledged that despite the various concerns that were voiced, most staff are aware that some kind of change in curriculum or at the very least some kind of update for the course is necessary. This particular opinion is found in descriptive code five.

Descriptive code six, “Lack of results”, is described by participants as a concern regarding seeing no results once the change has been made in the curriculum. This is particular concern was voiced in light of descriptive code 4; if staff are already under time constraints and they are asked or volunteer to help with the curriculum design of a course, there needs to be proof that the outcome of undergoing the curriculum design will have tangible benefits that remain relevant over long periods of time. This aligns with Brownell and Tanner (2012) on the need for incentives to help motivate change.

“What else, I think my major worry would be with this is something that you wouldn't know until you've actually implemented it is that it is you go to all this time and trouble to end up with a course, that gives you effectively the same outcomes. So, you invest huge amounts of time and effort in this, and, you know, huge amounts of passion and research and, and ways to try and get the course as productive and cool as possible, only to find that there's this typical sort of student apathy where you don't really engage them. So as a result, you don't get higher throughput rates, you don't get higher pass rates, etc. etc. But that is that is hypothetical, you won't know that until you actually do it.” – Respondent 1

“And so that's the one thing that I would like to say, and then the other thing is, will it still be relevant later on? So, as I've said, it changes. So, if you've been in university long enough, I think it goes in cycles. So, something will be very important when one [dean] is at, at the [helm], and then that person goes away, and then it goes down again, then we go to a new way of thinking, and then that person suddenly gets a bright idea and we do something else. And then think, 15 years later, then we go back to what the person 10 - 15 years back has told us. So that's one thing that makes it difficult to change, because you know that what you do today will change tomorrow.” – Respondent 8

2.4.2 Category 2: Institution

Category 2, labelled “Institution” incorporates the participants’ opinions that the changing of a curriculum happens on a much larger scale than just the department or university at large, but also has an impact on other higher education institutions and government departments. This category contains 3 descriptive codes:

Table 4: Table showing the three descriptive codes found within the category "institution" and the number of responses in each descriptive code.

Descriptive Code	**Responses in Descriptive Code**
1. Policy restrictions	4
2. Managerial support	1
3. Financial restrictions	1

Descriptive code 1, "Policy restrictions", was brought up by four participants who indicated that

"The barriers to changing a first-year curriculum are often associated with inter- and intra- institutional constraints. So, for example, if we change our first year, curriculum, we've actually got to make everyone else aware of, of what it is that we've done, because there are people in other departments that are expecting us to touch on particular topics." – Respondent 22

This respondent later added:

"The Department of Higher Education also has its you know, its standards, you know, there's a lot of flexibility in what you can teach, but at the same time, you have to also uphold particular standards, so, so that and often, you know, a first year, biology courses are supposed to have certain things these things that are kind of like cast in stone, that you, you've got to do this, you know, if you don't see you're not teaching plant biology." – Respondent 22

"So, for us, the barriers would be more to do with the fact that we're a small department, and that limits how much different expertise we have. So, for example, I would love to have more soil science, in our sort of undergrad curriculum, not necessary the first-year curriculum, but we've got to also work to our strength." – Respondent 15

"I don't know what processes you follow when you revise your courses, and also which bodies you've got the course itself registered with? Is it accredited by anybody's

because all of that will depend? Let's say for instance, you've got a course now that is recognized by SAAB for a particular purpose, or recognized by SANBI for a particular purpose. Then if you revise it, obviously, it has to go through being reviewed, whether it still meets the standards for its accreditation with the different bodies. So yeah, that's institutional and maybe departmental based. It depends on how many gatekeepers do you have to go through to actually implement any change or update?" – Respondent 18

In South Africa, the Council of Higher Education is responsible for the accreditation of public and private universities and relies on the National Qualifications Framework to ensure that the standard of education is being met. The redesign of any curriculum would need to continue to meet this standard.

Descriptive code 2, "managerial support" was brought up by one participant and describes that having support from members of faculty or staff in positions of power, such as head of departments or deans of faculty, goes a long way to help drive the implementation of changes and not just have change stagnate during the planning phase. This goes hand in hand with the need for incentive for change, Brownell and Tanner (2012) specifically mention recognition as one of the sought-after incentives, specifically for teaching staff.

"So, unfortunately, the education system and university teaching is not prioritized. Because as lecturers we not incentivized as much to focus on that component. And our research is what we measured by so there's that you have very few academic staff who are willing to contribute the amount of time and energy to the education component, and it needs buy in from a larger you know, it's not you can't be a one-man warrior in this you need to have buy in from, from almost from faculty level." – Respondent 9

Descriptive code 3, "financial restrictions", was brought up by one participant concerned about the financial implications of changing the curriculum.

"From a financial point of view, I think if solutions can be brought to the table, to see how to overcome those financial aspects, I think that would be quite important." – Respondent 14

2.4.3 Category 3: Students

The third category; “Students” refers to barriers that will arise due to the students. In this context, “students” refer to students that are currently enrolled for the course or will be enrolling in the course in the next year.

There are two descriptive codes within this category:

Table 5: Table showing the two descriptive codes found within the category “students” and the number of responses in each descriptive code.

Descriptive Code	Responses in Descriptive Code
1. No issue with students	4
2. Limitations of students	4

Descriptive Code 1 suggests that there will be no resistance to change from the students. No participant stated that there would be any resistance to change from the students themselves, seeing that unless the student is repeating the course, students would have nothing to compare it to

“The students won’t know better, because, well, except for the rather large chunk of them that are repeating. Um, you know, they're experiencing it new, they've never had the previous course to compare it to.” – Respondent 1

“Well, because it's a first-year course, I actually don't think that'll be a big issue, because I think they're coming in fresh, they don't actually have preconceived ideas on what it should look like or what they should be or how it should be. I imagine if you wanted to change drastically change the structure of second- or third-year courses, you would probably have more pushback, because they've got a rhythm and a vibe that they want. But I think a first-year course is probably not going to cause you as many issues with the students” – Respondent 5

Descriptive code 2 refers to the limitations of students being a potential barrier to change. The participants noted that the problem arises more with the circumstances from which the students are coming from, than with the students having an issue with the change. The state of high school education was brought up by 10 of the participants, noting that the lack of a plant-based biology education in a high school level contributes to a number of issues when trying to engage with students on a first-year level, not only in terms of knowledge and understanding but also with regards to low levels of interest and enthusiasm towards the course. Furthermore, large classes at a university level makes engaging with students on a personal level far more difficult than with smaller classes. This lowers the amount of time spent on each student and can potentially lower the quality of education that they receive. Large class sizes also make the running of practical or laboratory sessions highly logistically challenging.

" And the other barrier is that, but that is something that one can still work with is obviously the students the issue of plant blindness, the student's perception about plants and to change that. And that's not an easy thing to do. Especially working in an environment that we have now where all students need to all have to do BOT 161. So, you don't have students, taking the course just because they're interested in it, they have to do it." – Respondent 11

"The barriers. The major thing for me is class size. That is a major restriction, because you can really do a lot. But because of the number of students and I've experienced this firsthand, see, because I taught BOT 161 for number of years, and try to introduce things that made students more aware and to make it a bit more relevant for them. But I had challenges because of the number of students and going onto that because of the number of students it impacts on largely on the administrative processes on assessments. – Respondent 11

2.4.4 Category 4: Curriculum

The fourth category picked out of the thematic analysis is in regard to the curriculum itself. In this category there are two descriptive codes:

Table 6: Table showing the two descriptive codes found within the category "curriculum" and the number of responses in each descriptive code.

Descriptive Code	**Responses in Descriptive Code**
1. Curriculum requirements	8
2. Transformation	1

Descriptive code 1. "Curriculum requirements", is described by participants as barriers that may arise as a result of the structure of the curriculum or the content within the curriculum. This code discusses the need to ensure that the new curriculum will contain the necessary information to ensure that second- and third-year courses have a solid foundation to build their content around. The need to ensure that the new first year course blends well with other first year courses but also leads into other higher-level courses was voiced by participants. The need to ensure a lack of repetition, both between first semester courses and other second semester courses was also mentioned.

"And I think the other barrier is, what is what the structure of the second- and third-year courses look like, because those courses are probably reliant on what's being taught in 161. And if we change 161, and it's now not compatible with what's being taught above, that could cause issues going forward." – Respondent 5

This specific comment can be linked back to "2.4.2 Category 2: Institution" where Respondent 22 takes note of how other courses and institutions rely on students coming out of a first-year Plant Science module to have an understanding of certain fundamental basics.

"And then the other thing is, coming back to more the curriculum side is what's I'm going to introduce now in the new [module]. Will it still be relevant for the courses that follow up on it? Will, they give enough information, that I can just refer back to [the first-year plant science module] and the students know exactly what's going on? Or are they going to leave something out now. And then I have to incorporate it suddenly in my module and take extra time to spend on something that I assumed they had already done in the in [first year]. "– Respondent 8

". But it depends also, you can't change just one course. I mean, changing one course has a ripple effect on all the other courses that are in the discipline, and that need to be changed accordingly. Basically, you got to look at the bigger picture and see, if you change one, how does that affect the others? And what do we take out of those others? Or how do we rearrange them? So that the whole curriculum becomes sensible? So, it's not just one course it's all the courses together that need to form a comprehensive set of information and vision." – Respondent 20

Concern over the already packed curriculum was voiced, with participants stating that the current way of doing things results in having insufficient time to spend on everything because the curriculum is crammed full. Participants suggested that the new curriculum have slightly less content to ensure that what is covered is covered properly.

"And you know, then over the years it changed when they said that all students have to do all their biological sciences modules in the first year, the way that, you did it as well. And then effectively, lectures were reduced to two lectures a week and pracs were reduced to going from 12 to six. So, what happened is you got a cramming of content, which is not good. And secondly, we lost time, especially practicals, to work on skills. And so, but that all relates then to class size. So that's for me the major barrier, when it comes to changing the first-year curriculum. Because ideally, if we had more time and more lectures more practicals, we can actually do much more, we don't have that." – Respondent 11

"And yeah, so that's some of the things and then also, we don't want to do too much in BOT 161. So, we don't want to include everything. And then students, in any case, have so little time to spend with each specific aspect." – Respondent 8

"But I think the major thing is there the limitation on the, on the time that you have with a first-year students and, and the capacity that that a student can absorb. In a first-year module, I think that's, that's the biggest barrier." – Respondent 16

The second descriptive code, "Transformation" was mentioned by one participant and for this question. However, the need to embrace the concepts of decolonisation and transformation was also brought up on a number of occasions throughout the interviews in general, with participants suggesting that the new curriculum be more specific to the country we live in, moving away from using western examples but rather showcasing the diversity of South Africa in the way we teach and the examples that are used. This can be linked back to 2.4.3 Category 3: Students where Respondent 11 discusses the need to keep the content in the curriculum relevant for students. Although these topics are clearly integrated, I have kept them separate for ease of reading.

"…but it is extremely important for a lecturer to transfer their knowledge that they see in a textbook and make it applicable to not only the country that they work in, but even the area that they are teaching in." – Respondent 21

The respondent continued by saying:

"And if we take my students, for instance, the Zulu, they, many of them have a pretty good understanding of medicinal use of plants. And to use that as a springboard to make them aware of conservation issues, is a very good way of looking at it. And I'm not changing the curriculum. I'm just, I'm just going at it from another angle but I'm not changing the basic building blocks that they need before they can move to the next level. Yeah, that's the way I see it." – Respondent 21

2.4.5 Category 5: No barriers

The final category, notably only brought up by only one participant, is the category labelled "Not Applicable". The participants initial response was that there are no barriers, his response remained the same when asked to clarify. As a follow-up question, the participant was asked whether they believed lecturers or students would show resistance to change, to which they gave the following response:

"I don't think there will be resistance it will be more a kind of situation where the lecturers within the different disciplines would want more of their specialty in the module incorporated, yeah … I don't want to just speak to them for five minutes, I would rather have a full lecture with them than five minutes in telling them of [my subject specialty]" – Respondent 3

2.5 Discussion

Despite the important role that academic staff play as agents of change (Mathieson, 2012), our findings suggest that the preconceived barriers arising as a result of academic staff (category 1) remain the largest potential obstacle that needs to be overcome if we are to successfully implement curriculum change. This aligns with the literature about academic reform efforts, which suggests that it is the people involved in the change process that will cause the largest barrier.

Change in the higher education sphere has been documented to be very difficult, despite the literature suggesting that it is necessary (Brownell and Tanner, 2012; Henderson, *et al,* 2011). Two descriptive code groups in the category ("No change necessary" and "resistance to change") agrees with research by Annalas (2021) describing the oppositional agency group that believes that change is not necessary. These two groups can also be compared with Pardo de Val and Martínez Fuentes

(2003) group of “distorted perception” which also suggested a lack of willingness to change and lack of foresight as to why it is necessary. It was explicitly mentioned by a number of respondents in my study that older academic staff may be less open to change than younger staff. Pardo de Val and Martínez Fuentes (2003) also mention that embedded routines may result in a failure to implement organizational changes. A study by Edgcumbe (2022) has shown that open-mindedness tends to decrease with age and have also indicated that the decrease in open-mindedness may have detrimental impacts on decision making as adults are working later into their lives.

Brownell and Tanner (2021) state that insufficient training, inadequate time and lack of incentives are of the most commonly referenced barriers to change within higher education reform. Interestingly, insufficient time was the only one of these “big three” that made a substantial appearance in my study, that being “time restraints” in category 1. Implementing planned changes is no small feat, it requires that course materials and resources are changed, as well as all official course documents (Cooper, 2017). The lack of incentives due to most universities being research- and not teaching-driven was mentioned by one participant (Respondent 19) but did not emerge as a major point of discussion. Furthermore, at no point does any participant mention that a lack of training is an issue. This can be linked back to professional identity; if someone only sees themselves as a researcher, they have no need or interest in teacher training, which can be an enormous barrier to change (Brownell and Tanner, 2012). It appears that, in terms of teaching, participants have complete faith in their abilities. As there is often no policy requiring academic staff to have a formal teaching qualification (however this varies depending on the institution), and most academic teaching staff do not hold such a qualification, it would be beneficial for future research to explore if this level of confidence remains true in the South African Higher Education context.

Despite the various concerns from participants regarding the potential barriers that may be faced when redesigning the curriculum of a course, a substantial portion of participants acknowledged that they are aware that some kind of change in curriculum, or at the very least some kind of update for the course, is necessary in terms of BOT 161.

The second category, institution, deals with the barriers that may arise when dealing with the institution or organisation at large. The first descriptive code deals with policy. In this case, participants discuss the need to ensure that the new curriculum is properly accredited by external sources. The second descriptive code deals with the need for managerial support. Cooper (2017) states that strong leadership is fundamentally important in implementing curriculum change. They suggest that people in leadership positions need to have a strong disciplinary knowledge as well as a formal knowledge of education theory and teaching (Cooper, 2017). Curriculum design is a specialist skill (Cooper, 2017) and, as such, should be utilised by institutions which are planning on redesigning course curricula. The need for support from individuals in a managerial position was indicated by participants in my study. Auerbach and Schussler (2017) re-emphasise a point made by Kluger and DeNisi (1996) stating that when it comes to academic reform, staff are more likely to be committed if they understand the goal that managerial positions are trying to achieve and why they are trying to achieve it.

The third category, relating to barriers that may be faced as a result of students within the course, has a wide spectrum of answers. The first group of participants believed students would not pose a barrier, as they would not be aware of any plans for change, or aware of any implementation of change unless they are repeating the course. The second group in this category speaks more to issues surrounding the students rather than the students themselves. Large classes, (although this is institution specific as not all institutions service a large number of students), impact what you can do with students in terms of pedagogical changes as well as how you organise practical or laboratory work. Issues such as uncertainty about class sizes and venue allocation can impact how lecturers plan their contact times with students (Cooper, 2017). Furthermore, large classes at a university level make engaging with students on a personal level far more difficult than with smaller classes. This lowers the amount of time spent on each student and can potentially lower the quality of education that they receive, a point raised by Respondent 11. Cuseo (2007) indicates that large class sizes can impact students in several negative ways, including fewer opportunities to interact with the course material as well as with their instructors. This was echoed by Ballen and colleagues (2018) that found in STEM subjects women are especially negatively impacted by large class sizes, which they suggest is due to underrepresentation in the class or field, along with a number of other complex reasons. In this study (Ballen, *et al,* 2018), their largest class size was 200 students, a number far smaller than the introductory plant science course at the University of Pretoria. An exploratory study on the implementation of differentiated instruction indicated that it was nearly impossible to do so in large classes (indicated to be between 50 to 500 students) (Turner, *et al,* 2017). This suggests that when catering to a large number of students, pedagogical change is difficult to implement.

Although not specifically mentioned by participants, it is also important that we take the socio-economic background of our students into account when redesigning higher education curriculum. Higher education is not as easily accessible in an African context as it is elsewhere in the world (Kaliisa, 2017). We need to take into consideration that not all students will have access to mobile learning devices such as laptops and cell phones and that if they do have access to these devices, they may not be compatible with modern university systems (Kaliisa, 2017). Taking this into consideration may change how we structure our courses and how we choose to implement certain pedagogical changes and interactive elements into our classes.

The fourth category, dealing with curriculum itself, discusses the need for coherency between the new course and subsequent higher-level courses. Furthermore, a lack of coherency between what the new curriculum requires and what the institution has available in terms of facilities can result in challenges with implementation (Cooper, 2017). This particular point was raised by a participant in a smaller university that had a very limited range of expertise in terms of lecturing staff. For them, implementing new course material that does not fall under the expertise of the current staff would require that they work outside of their respective fields. This would require preparation time, which we have already seen is limited, and holds little reward.

2.6 Limitations of the Study

There are a number of limitations that need to be considered with regards to this study. Although the data collection methods used in this study did not require a specific sample size, I believe that a larger sample size would have been beneficial with regard to the generation of ideas and collection of opinions in terms of barriers to change. 116 individuals were contacted and asked to take part in the study, however only 23 responded. A *chi*-square test was conducted to ensure that there was no bias between the participants fields of research and their responses. Secondly, the majority of the participants were employees of one of the 14 universities taking part in the study.

Although the study aimed to gather the independent ideas and opinions of the participants, it must be noted that the shared space may have influenced participants. This study had a very broad focus as can be seen on the wide spectrum of results. It is suggested that future research focus in on more specific areas that arose as part of this study but could not be investigated in depth due to the exploratory nature of this study. These suggested areas include (1) barriers to changing content in curriculum, (2) barriers to pedagogical change in curriculum, (3) the impact of student background on the implementation of curriculum change and (4) the impact that older academic staff members have on implementing curriculum change.

2.7 Conclusion

This study indicates that the greatest barriers to curriculum change in higher education are predicted to come from staff that are directly or indirectly involved with the curriculum change. Their biggest barrier is the time restraints staff face with regards to implementing the change while balancing their research and personal lives.

Future Research

The *Vision and Change* document (AAAS, 2011) was initially intended for use by general biology courses, although it is applicable to other courses in the biological sciences field and can be adjusted to be more specific in this regard. The results that I obtained from this study echo the board design of Vision and Change. I have now identified which core concepts and competencies the majority of my participants believed should be including in an introductory plant science module and so future studies should focus on a few core aspects. Firstly, the broad concepts and competencies should be refined, not only in terms of specificity but also in the context of the University of Pretoria. It became very apparent during the initial iteration that each of the universities function somewhat differently and have different departmental dynamics and areas of focus. Future studies should focus on refining these concepts and competencies, specifically within the context of the University of Pretoria.

Secondly, the needs of industry may also influence the content and competencies that are taught on a tertiary education level. Graduates need to graduate with both knowledge and skills that make them employable. A study that aims to identify what industry needs in its graduate students may influence what is taught in higher education institutions, specifically on a second year, third year and post-graduate level.

Lastly, identifying what content and competencies students are coming into the course with may help pinpoint specific areas that need to be addressed within the student body. Areas of content that are prone to misconceptions and basic competencies such as lab etiquette and safety and use of laboratory equipment could be addressed, setting the students up for greater success.

General Conclusion

Despite curriculum change being documented in the literature as a difficult endeavour, I managed to identify areas of majority amongst the participants with regards to what is important in an introductory plant sciences course as well as successfully explore the barriers to change in higher education.

Specifically, my research questions for this study were

1. What core concepts and core competencies should be included in an introductory plant science course?
2. What barriers could arise throughout the process of implementing curricular changes in an introductory plant science course?

The data showed that participants considered three core concepts and three core competencies to be the most important to incorporate into an introductory plant biology course in South Africa: Structure and Function, Pathways and Transformations of Energy and Matter, and Evolution were the three *Vision and Change* concepts that were chosen above the rest. Process of Science, Interdisciplinary Nature of Science and Integration of Science and Society were the top three *Vision and Change* competencies that were chosen by participants as most important of the seven.

“Curriculum is the expectations for what will be taught and what students will do in a program of study. It includes teacher-made materials, textbooks, and national and state standards.” (Delaware University, n.d.). Curriculum is not one thing, but rather many things, each of which serves a purpose. In a field as broad as the plant sciences, I think it is unrealistic to narrow an introductory plant science course down to one or even two concepts, however, the *Vision and Change* concepts chosen by participants in this study should be viewed as overarching themes that help to organize all of the other content of the course. Participants indicated that an introductory plant science course should aim to spark interest in students. However, an introductory plant science course also needs to be functional. This study has given us a broad idea of where to start in terms of making a course more focused and purposeful. I believe that with the inclusion of the needs of industry, future research would be able to clarify this even further.

With regards to the core competencies, it is clear that participants believe that "hands on practical sessions" are incredibly important. This aligns with the process of science being one of the more important competencies. Again, mastering the process of science requires that students understand multiple components of science. The benefit of focusing on one or a few competencies is that students will receive multiple interventions of this competency, which may help improve their abilities in science. However, I believe that narrowing a curriculum down to only one competency may be unrealistic and that we should use the teaching of competencies to spark interest in all science, not just plant science. The importance of practical skills should not be overlooked, but I believe that the voice of industry is even more important here than in core concepts.

The outcomes of chapter one aligns with the findings regarding barriers to change in chapter two; the biggest barrier to curriculum change in higher education comes from the academic staff involved in the change process. We see in chapter 1 that achieving consensus regarding content and competencies is not easy, and the literature tells us that group decision making on any level is complicated. This being said, participants did not indicate that it would be a lack of agreement that would be the greatest barrier, but rather lack of time to develop and implement the changes.

The use of a curriculum specialist or a group of individuals that could help develop content, practical sessions and assessments would help to mitigate this issue. A group of individuals like this would also have the capacity to further this research as per the recommendations listed above, to ensure that the reformed curriculum meets the international standard we would want to achieve, but also ensuring that our graduates leave our campuses with skills that are applicable and sought after in the working world.

“Expertise comes not from having information, but in knowing how to use it. It is this profound shift in thinking that necessitates that we, the biology educators, endow our students with opportunities to think critically, cross disciplinary boundaries, and develop problem-solving skills – all while working with information on a scale previously unimaginable” (McLaughlin & Mets, 2016).

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Appendix A

Participant consent form

Information Leaflet and Informed Consent

TITLE OF STUDY: Developing Outcomes for a First-Year Plant Science Module: A Case Study (Provisional)

Dear Dr/Prof _________________

Introduction and Background

You are invited to participate in a research study. The following information will help you decide if you want to participate in the study. Before you agree to take part please read through this short document to fully understand what is involved. It is important to emphasize that you are being asked to participate because you are considered an expert in the field of Plant/Soil Sciences and your opinion is highly valued by the team of experts dealing with curriculum development.

Nature and Purpose of the Study

In light of the need for curriculum transformation, we have set out to improve the learning outcomes of the first-year plant science module offered at the University of Pretoria. Using the ideals set out in the "Vision and Change" document, our objective is to develop appropriate learning outcomes for a first-year plant science course that are locally applicable and of an international standard. Our research questions will specifically revolve around both content and competency outcomes that learners should have acquired upon completion of the module. We will also be probing deeper into the potential barriers and predispositions to change.

For more information on Vision and Change:
https://view.genial.ly/5f7a0b470408af0da67b0c50/interactive-content-untitled-genially

Explanation of Procedures

Data collection will take place in the form of a semi-structured interview. Prior to the interview you will be supplied with the list of questions that will be discussed with you. The interview will be scheduled at a time and date preferable to you, using the Google Meets platform, and will take approximately one hour. During the interview there may be follow up questions that lead to discussion points not listed in the supplied document. With your, permission the interview will be recorded and later transcribed. After the transcription and analysis of the data, you will be sent a document containing a summary of the interviews which you will be asked to review.

Risk and Discomfort

There are no risks to you taking part in this research study. Your opinions will remain anonymous to the participants of the study and in any publications that may arise from the study, however due to the methods used in the study you will not remain anonymous to the research team. In any publications originate from this study, all data will be anonymous.

Benefits of the study

Although, you will not benefit directly from this study, the results obtained from this research will allow the research team to develop learning outcomes that are of an international standard and locally applicable and ultimately improve the first-year Plant Science curriculum at the University of Pretoria.

Your Rights as a Participant

Your participation in this study is completely voluntary. You have the right to withdraw from the study at any time. Your withdrawal will have no consequences in anyway. You have the right to ask questions at any point during the study. Your opinions will remain anonymous to fellow participants throughout the study as well as in any publications that may follow the study.

Ethics Details

This study has received written approval from the Ethics Committee of the Faculty of Natural and Agricultural Sciences at the University of Pretoria (reference number: NAS093/2020).

Contact Details

If you have any questions about the study or your role as a participant please contact myself, Megan Roberts, at u16076771@tuks.co.za or my supervisor Dr Angelique Kritzinger at angelique.kritzinger@up.ac.za.

Confidentiality

All information that you provide will only be available to the research team members. Your opinions will be recorded anonymously in any publications that might follow this study.

If you would like to participate in this study, please complete the attached consent form and email it to u16076771@tuks.co.za. **If you agree to participate in this study, could you please indicate three (3) dates and times that you would be available to participate in an interview of approximately an hour.**

CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that the person asking my consent to take part in this study has told me about the nature, process, risks, discomforts and benefits of the study. I have read this form and I understood the information regarding the study. I am aware that the results of the study, including personal details, will be anonymously processed into research reports. I am participating willingly. I have had time to ask questions and have no objection to participate in the study. I understand that there is no penalty should I wish to discontinue with the study and my withdrawal will not affect any treatment in any way.

I have received a signed copy of this informed consent agreement.

Participant's name .... (Please print)

Participant's signature: .... Date............................

Investigator's name: Megan J Roberts .... (Please print)

Investigator's signature: .... Date: 12 October 2020................

Witness's Name .... (Please print)

Witness's signature: .... Date...........................

Appendix B

Interview Guideline

Interview Guideline

The questions you will be asked during the interview are shared with you below in order to allow you time to prepare.

1. Is plant blindness/plant awareness disparity lack of interest in plants a problem in your institution?
2. Do you have issues getting students to enrol for your plant science degrees?
3. Do you think a first-year plant science module should have;
    a. A narrow approach, covering a few concepts in detail,
       For example:
       • *Structure and function*
          • *Plant tissues and organs*
          • *Transport mechanisms in plants*
          • *Plant responses to biotic factors*
          • *Plant responses to abiotic factors*
       OR
    b. A broad approach, touching on multiple concepts within the field?
       For example:
       • *Evolution*
       • *Pathways and transformations of energy and matter*
       • *Information flow, exchange, and storage*
       • *Structure and function*
       • *Systems*

    Please explain your answer.

4. Which of the following concepts do you think should be incorporated in a first-year plant science module? Please explain.
    a. Evolution
    b. Pathways and transformations of energy and matter
    c. Information flow, exchange and storage
    d. Structure and function
    e. Systems
    f. Other
5. Which of the following threshold competencies do you think should be incorporated in a first-year plant science module? Please explain.
    a. Process of science
    b. Interdisciplinary nature of science
    c. Integration of science with society
    d. Communication
    e. Collaboration
    f. Understand and interpret data

    g. Quantitative competency

6. Which of the above listed concepts and competencies do you think should **not** be taught in a first-year plant science module? Please explain.
7. Before you read the information leaflet, have you ever heard about Vision and Change?
8. What do you think the barriers to changing a first-year curriculum will be?
9. Do you have any suggestions as to how we might overcome these challenges/barriers?
10. What kind of resistance do you foresee would lecturers have if this change is being introduced?
11. What could potentially be a good selling angle for us to motivate people to be willing to take part in this change process?
12. How important do you think hands on practical sessions are for a first-year plant science course?

Appendix C

Questionnaire

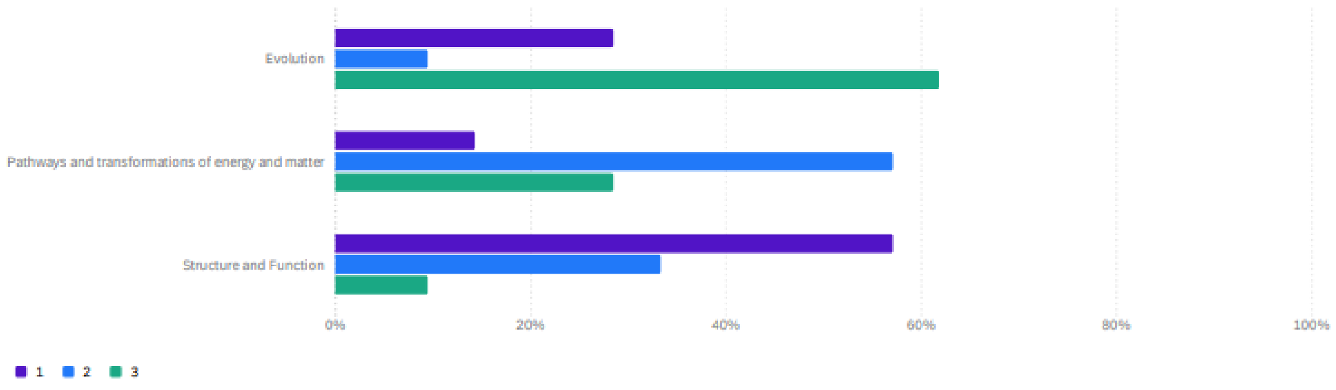
1. What gender do you identify with?
    a. Female
    b. Male
    c. Other
    d. Prefer not to say
2. Please indicate the ethnic group you identify with?
    a. Asian
    b. Black African
    c. Caucasian
    d. Coloured
    e. Indian Other
3. Please indicate your field of research/area of expertise by placing yourself in one of the broad disciplines of Plant Science as indicated below.
    a. Biodiversity (Ecology, Taxonomy, etc)
    b. Medicinal Plant Sciences
    c. Other, please specify
    d. Plant Biotechnology
    e. Plant Pathology
    f. Plant Production (Agricultural Sciences)
4. Please indicate how long your have been lecturing Plant Science.
    a. 0-5 years
    b. 11+ years
    c. 6-10 years
5. Analysis of the data from the initial interviews indicate that of the original 5 concepts, the following 3 concepts were most commonly chosen as being important to cover in a first year plant science module. Please rank these in order of importance.
    a. Evolution
    b. Pathways and transformations of energy and matter
    c. Structure and function
6. Data from the initial interviews suggested that there was potentially a divide in how lecturers view the purpose of a first year module. Should a first year plant science course be used as a means to spark interest in students solely as a means to impart the fundamental basics of the field?
    a. Basics
    b. Interest
7. Data from the interviews indicated that the following three competencies were the most important for a first year course. Please rank these three in order of importance
    a. Process of science
    b. Interdisciplinary nature of science
    c. Link between science and society

8. The BioSkills Guide is a tool that was developed to help interpret the Vision and Change core competencies. Each competency is broken down into a number of key learning outcomes. For the "Science and Society" competency, please rank the following learning outcomes in order of importance of integration into a first year plant science module
    a. Ethics - Demonstrate the ability to critically analyse ethical issues in the conduct of science
    b. Societal Influences - Consider the potential impacts of outside inflluences on how science is practiced
    c. Sciences Impact on Society - Apply Scientific reasoning in daily life and recognize the impacts of science on a local and global scale
9. The BioSkills Guide is a tool that was developed to help interpret the Vision and Change core competencies. Each competency is broken down into a number of key learning outcomes. For the "Process of Science" competency, please rank the following learning outcomes in order of importance of integration into a first year plant science module.
    a. Scientific Thinking - Explain how science generates knowledge of the natural world
    b. Information Literacy - Locate, interpret and evaluate scientific information
    c. Question Formulation - Pose testable questions and hypotheses to address gaps in knowledge
    d. Study Design - Plan, evaluate and implement scientific investigations
    e. Data Interpretation and Evaluation - Interpret, evaluate, and draw conclusions from data in order to make evidence-based ...
    f. Doing Research - Apply science process skills to address a research question in a course-based or independent research experience
10. The BioSkills Guide is a tool that was developed to help interpret the Vision and Change core competencies. Each competency is broken down into a number of key learning outcomes. For the "Interdisciplinary Nature of Science" competency, please rank the following learning outcomes in order of importance of integration into a first year plant science module.
    a. Connecting Scientific Knowledge - Integrate concepts access other STEM disciplines
    b. Interdisciplinary Problem Solving - Consider interdisciplinary solutions to real world problems

Appendix D

Qualtrics Graphs

Analysis of the data from the initial interviews indicated that of the original 5 concepts, the following 3 concepts were most commonly chosen as being important to cover in a first year plant science module. Please rank these in order of importance. 21



The data from the interviews indicated that the following three competencies were the most important for a first year course. Please rank these three in order of importance. 16