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STELLENBOSCH UNIVERSITY ENGINEERING AND EDUCATION STUDENTS' RANKED PRIORITIES OF SCIENCE- AND TECHNOLOGY-RELATED GLOBAL PROBLEMS

by

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SUMMARY

In 1984 Bybee used 262 science educators from 41 countries to develop an instrument for measuring their ranked priorities of science- and technology-related global problems. In 1995 the original Bybee scale was updated and clarified, and a new 15-item version, the Le Grange Global Priorities Instrument (LGPI), was piloted, refined and administered in fifteen schools to 946 secondary school pupils speaking three different home languages in two provinces in South Africa. In this study the LGPI was refined and updated to a 12-item scale and to include three qualitative questions. The LGPI is renamed, in this study, as the Revised Le Grange Global Priorities Instrument (RLGPI). The RLGPI was administered in the form of a best-worst scale to 114 Engineering and Education students at Stellenbosch University, South Africa.

The study is an extension of the work of Bybee and Mau (1986) Bybee and Najafi (1986), Ndodana, Rochford and Fraser (1994), Le Grange, Rochford and Sass (1995) and Le Grange (1996), and needed to be updated two decades after the last research on the topic was conducted in South Africa.

Of a total of 120 questionnaires distributed, 114 were completed and were used in computing the results of the study. A total of 58 questionnaires were completed by education students and a total of 56 questionnaires were completed by engineering students at Stellenbosch University.

The data were collected during the period May to August 2016, using 15-minute slots as part of normal class time of formal instruction; 95% of the questionnaires were complete and usable. Mean ranking scores were compared between attributes and groups using mixed model repeated measures ANOVA. For post hoc testing Fisher least significant difference (LSD) was used. Analyses were conducted using Statistica 13. This was for the purpose of disclosing significant similarities and differences between the responses to the RLGPI items. A test-retest correlation of $r = 0.82$ ($n = 26$) was obtained for the RLGPI instrument as a whole using smaller samples of available students in 2016.

The results reveal that the overall differences between the fourth-year education students and fourth-year engineering students were relatively minor, except for the items *Loss of biodiversity* and *Energy needs*. The results showed a statistically significant difference ($p<0.01$) between the engineering students' and the education students' ranking of the item *Loss of biodiversity*. The engineering students and education students ranked *Energy needs* with a statistical difference at the $p<0.01$ level. Both samples ranked *Fresh water supplies, World hunger and food resources* and *Human health and disease* as their top three priorities.

Rankings done by the whole group on the RLGPI as a whole showed little differences, except for items *World hunger and food resources, Loss of biodiversity, Ignorant decision makers*. The whole female group ranked *World hunger and food resources* at 1st place and males ranked it at 2nd place, which was statistically significant at the $p<0.01$ level. *Loss of biodiversity* was ranked at 3rd place by the whole female group and the whole male group ranked it at 8th place. This difference is statistically significant at P value = 0.00. All females as a whole ranked *Ignorant decision makers* at 8th place and the males ranked it at 6th place. This difference was significant at $p = 0.02$. The top-ranked items for all the samples were *Fresh water supplies, World hunger and food resources, Human health and disease; and Population growth*. These four items relate to basic human needs for long- and short-term survival.

There is consequently a need for an updated curriculum that can meet all the needs that society might have as these needs always change with time. In this study the importance of keeping track of students' priorities when developing curriculums are emphasised. This study focussed on current environmental problems and the 17 goals for sustainable development set by the UN. Current issues like environmental destruction and gender inequality are just some of the issues that findings in this study prove to be problems that need to be addressed in the science curricula, as Bybee (1984) suggested.

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LIST OF ABBREVIATIONS

AIDS (Acquired Immunodeficiency Syndrome)

BWS (Best-Worst Scaling)

CFC (Chlorofluorocarbons)

CLM (Constructivist Learning Model)

DEA (Department of Environmental Affairs)

EE (Environmental Education)

FET (Further Education and Training)

HIV (Human Immunodeficiency Virus)

LGPI (Le Grange Global Priorities Instrument)

REIPPP (Renewable Energy Independent Power Producer Procurement Programme)

RETs (Renewable Energy Technologies)

RLGPI (Revised Le Grange Global Priorities Instrument)

SD (Sustainable Development)

SDE (Sustainable Development Education)

STS (Science-Technology-Society)

UN (United Nations)

UNEP (United Nations Environment Programme)

UV (Ultra-Violet)

UVR (Ultraviolet Radiation)

WWF (World Wildlife Fund)

CHAPTER 1
INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

This chapter will introduce the study. The chapter is divided into twelve sections. Section 1.2 will discuss the statement of the problem. Section 1.3 states the purpose of the study. Section 1.4 describes the origin and background of the research. Section 1.5 discusses the importance of the problem. Section 1.6 presents the hypotheses. Section 1.7 provides a clarification of terms. Section 1.8 discusses the limitations of the study. Section 1.9 states the assumptions of the study. Section 1.10 describes the research approach. Section 1.11 outlines the structure of the thesis. Section 1.12 provides a summary of the chapter.

1.2 STATEMENT OF THE PROBLEM

The negative impact on the environment as a result of the increasing population and human consumption is becoming more apparent each year. Some of the greatest environmental and societal problems in the world are the consequence of developments in technology and science, for instance, harmful gas emissions from cars, pollution from producing electricity, agriculture methods using dangerous chemicals, forest destruction from logging and for housing developments, infectious diseases in urban areas, etc. However, technology and science are also responsible for most of the solutions to these problems, such as medicine for infectious diseases, biofuels for less harmful gas emissions, sun panels to harvest renewable electricity, and so forth. Engineers are some of the major contributors to the causes of these problems, but also some of the most important role players when it comes to solving these kinds of problems (Miller, 2011). Some of the greatest achievements and discoveries in technology and science were based on work done by engineers. The invention of the steam train, bridges, roads, airplanes, electricity, water purification and distribution plants are some of the examples of areas where engineers made a significant difference in the world. These changes improved the lives of billions of people, but unfortunately many of these inventions have also had negative effects on the environment. Some of the inventions mentioned depended on the use of fossil fuels, which are a non-renewable resource and the combustion of such fossil fuels produces air pollution.

Educators are responsible for educating people all around the world about these inventions, as well as the problematic impact that these scientific and technological discoveries are having and have had on the natural environment. People involved with education have the power to change people's minds and their way of thinking, which could potentially effect change in whole societies. George Bernard Shaw says cogently: "Progress is impossible without change, and those who cannot change their minds cannot change anything" (Shaw, 2016, p. 1). Educators are responsible for generating these kind of changes. Education is a key lever in solving science- and technology-related global problems. To know how to solve these problems related to science and technology, we might need to know what is in the minds of people who have the potential to solve these problems (Holman, 1993), in this case engineers and educators.

Bybee (1984) had the same idea and suggested there were 12 global environmental issues/problems around the world and indicated what kind of scientific knowledge and processes might be taught to address these problems (See appendix, p.133). In 1995 the original Bybee scale was clarified and updated by Le Grange (1996) and a new 15-item measure, the Le grange Global Priories Instrument (LGPI), was developed (Appendix). For many years educators have realised that the growth of student knowledge and understanding of science is closely tied to the personal experiences of students (Bybee, 2008). The constructivist learning model (CLM), suggests that learning is a social process during which students use what is already known to make sense of new experiences (Tobin & Tippins, 1993). With this knowledge it is easy to understand why the priorities of engineers and educators should be made known to curriculum developers in higher education as well as in primary and middle school education, because that which is relevant to students might have a bigger impact on influencing their ways of thinking to prioritise their problems according to the major science- and technology-related global problems.

The United Nations has identified 17 sustainable development goals that focus on the key problems that need to be addressed in order to transform the world (United Nations, 2016). These include goals such as: no poverty, no hunger, good health and wellbeing, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for achieving these goals (United Nations, 2016).

The RLGPI includes most of these goals put forward by the United Nation. In this study we focus on how education and engineering students prioritise the problems, but it is actually important that all people on earth know and learn about these problems listed by the United Nations. To be successful in reaching all of the 17 goals set by the United Nations, everyone needs to be involved in doing their part to change the world, be it those engineering, education, business, health care, agriculture, even students and lecturers at university. One of the roles of education is to create citizens who are responsible and who want to do their part in solving problems in the world. Therefore research needs to be done to investigate the priorities of all citizens, to see if they correlate with problems in society, such as addressing the 17 goals listed by the United Nations and the items on the RLGPI. Results from research done by administering the RLGPI can be used to adapt the school curriculum so that everyone can become aware of current issues.

In this study we also investigate the possibility that a persons' profession and gender might influence how they prioritise science- and technology-related global problems. Gender has played a role in peoples' lives since the dawn of civilisation (Hendley & Charles, 2016). Girls are treated differently while growing up as are women in the work place; this might have an influence on how they prioritise problems in the world (Hendley & Charles, 2016). Engineers and teachers might have very different priorities since their professions are very different; engineers work directly with technology and science, while teachers work directly with people and knowledge.

1.3 Purpose of the study

This study has five main purposes that are outlined below:

1. The first purpose was to revise and update the two-decade old LGPI to now become the RLGPI.
2. The second purpose was to establish whether students' rankings of global priorities have changed over time.
3. The third purpose was to administer the RLGPI to fourth-year engineering and education students to find out whether there are any significant differences in the way students from different disciplines rank global science and technology problems.
4. The fourth purpose was to establish whether there are gender differences in the way students rank science- and technology-related global problems.
5. A fifth purpose was to establish the reasons behind students' top-ranked items.

The study also has a broad purpose of providing curriculum developers with insights into how to develop issues-based curricula at school and university levels. The primary function of science education at the middle, junior and high school levels is to provide students with an opportunity to explore science in their lives and to become comfortable and personally involved in it. Consequently, the science curriculum might be able to create citizens who understand science in ways that will enable them to participate intelligently and make decisions on how science and technology can change society most effectively. Such a science curriculum is human and society focused, problem-centred and responsive to local issues (Mai, Halim, Yaseen & Meerah, 2012). This function of science education is, of course, also extended to higher education. This study might therefore provide curriculum developers at school and university level with insights into to how students think about science- and technology-related global problems. The study could contribute to creating a model for developing an STS (science-technology-society) and issues-based higher education curriculum.

The explosive progress of science and technology up to the 21st century brought prosperity and enriched the quality of life for much of humankind. However, the advance of science and technology raises important ethical, safety and environmental issues, including possible negative applications that threaten humankind's own future. Since progress in science and technology is expected to accelerate and will be necessary for sustainable human development in the 21st century, wisdom will be necessary to manage such developments so that they do not impact negatively on the environment and on the lives of future generations.

The most pressing problems we face today include; to find a sustainable balance between economic development and global warming, preventing terrorism, controlling infectious diseases, and assessing the potential health benefits and ethical factors related to cloning technology. International efforts to address these problems are needed now more than ever. The advancements we have achieved through science and technology, but also the destruction they have caused, are what symbolise the 'lights and shadows of science and technology' (Yoshikawa, 2005). Opportunities need to be grasped, but the risks must also be controlled. Health, meeting energy needs and many other aspects of human welfare are dependent on continued progress in science and technology.

In 1984 Rodger W Bybee designed an instrument for measuring people's priorities of science and technology-rated global environmental problems. A decade later Lesley Le Grange updated the original Bybee scale into a new 15-item measure, the Le Grange Global Priorities Instrument (LGPI). Twenty years later it is now necessary to update the instrument again, because environmental issues are always changing and so are peoples' priorities. This relates to the first purpose of the study. Roper Starch (1994) writes that when issues are relevant to people's immediate lives, they are much more likely to be of greater concern to them. South Africa is a heterogeneous nation of many cultures and languages. Therefore the basic needs of South Africans differ widely in terms of context, including urban and rural settings, the environment, culture, gender and education. It follows then that environmental priorities in their immediate environments might also differ quite drastically. People's gender could have an influence on the environmental issues that they prioritise. Men and women experience different circumstances while growing up and this could lead to their having a different outlook. The same applies to those who study different disciplines in higher education, who may therefore prioritise science- and technology-related problems differently.

1.4 Origin and background of the research

As mentioned, in 1984 Bybee used 262 science educators from 41 countries to develop an instrument for measuring their ranked priorities of science- and technology-related global problems. In 1995 the original Bybee scale was updated and clarified, and a new 15-item version, the Le Grange Global Priorities Instrument (LGPI), was developed. Now, in 2016 the LGPI was updated and the RLGPI is used in this research. This study is an extension and application of the work done by Bybee and Mau (1986), Bybee and 'Najafi (1986), Ndodana, Rochford and Fraser (1994), Le Grange (1996) and Le Grange, Rochford and Sass (1996). Bybee (1984) recommended 12 global science and technology problems around which science education should be taught. Bybee's (1984) idea was that the 12 issues should be fitted in student awareness and knowledge that fit within the general science education curriculum.

In 2002 Paul Crutsen suggested that we had moved beyond the Holocene and entered a new epoch, the Anthropocene, because of the global impact on the environment of increased human population growth and economic and scientific development (Zalasiewicz & Williams, 2008). Humans are currently in control of events on earth in a way that is unprecedented in history. Humans have the power to destroy nature or to nourish it. And it is through science and technology that some of the most extensive environmental destruction has been caused. But as recent research shows, discoveries in science and technology have also made it possible to find solutions to the problems that the world is facing. These problems correlate with the original Bybee scale (1984) of science- and technology-related global problems and with the RLGPI, used in this study.

1.5 Importance of the problem

The world is faced with all kinds of problems. Some of these problems have accelerated in the last 20 years. They include problems such as deforestation, ocean depletion, energy production, overpopulation, Ebola, HIV and fresh water scarcity (Chakravarty, Ghosh, Suresh, Dey, & Shukla, 2012). Since the beginning of the Industrial Revolution some 250 years ago, sea water acidity has increased by 30%. It should be noted that increasing sea water acidity lowers the ocean's natural 'basic' or 'alkaline' status and unnaturally forces the acid base balance of sea water towards a higher level of acidity (Laffoley & Baxter, 2009). As far as water availability and quality are concerned, hydropower, nuclear power and thermal power account for 10% to 15% of global water consumption, and the volume of water that evaporates from reservoirs exceeds the combined freshwater needs of industry and domestic consumption (Sovacool, 2014). In just 41 years the earth's population has already increased to 7.4 billion in 2016. This is an incredible growing rate of 1.13% per year (Martins, 1996). The 2004/5 UN Year Book reported that 15 million people died annually from infectious diseases such as Ebola and malaria, making them the world's leading cause of death and accounting for 25% of global mortality (United Nations Environment Programme, 2014). Clean, drinkable fresh water sources are becoming less available. Water availability is expected to decrease even more in many regions. Yet future global agricultural water consumption alone is estimated to increase by more than 19% by 2050 (Mekonnen & Hoekstra, 2011). These problems are all science- and technology-related problems. They are informed and affected by scientific knowledge and in turn they are related to issues that face society. The whole science and technology debate informs this study. Society wants and needs to be informed about these kind of problems currently related to developments in science and technology.

Scientists alone can't be responsible for solving these science- and technology-related global problems. This is why the public understanding of science is so important. This all forms part of the 'democratisation of science'. There is a growing mistrust of science in society (Carolan, 2006). Society feels excluded from scientific knowledge and they feel unable to contribute directly to science knowledge, as science has become an activity of elitist groups. This issue has to be addressed by making science a more open and democratic activity. This can be done by having more informative public discussions and including the public in discussions on the science curriculum. At the UNESCO World Conference on Science it was said that whilst extraordinary advances in the sciences are expected, there is a need for a vigorous and informed democratic debate on the production and use of scientific knowledge. The scientific community and decision-makers should seek the strengthening of public trust and support for science through such a debate (United Nations Educational, Scientific and Cultural Organization, 1999). Citizens, future teachers and engineers need to be knowledgeable about science- and technology-related problems and how they are prioritised in terms of funding by governments, etc. This is important for engineers and teachers, because the implications of this study could make a difference for those who develop undergraduate engineering and education programmes at university. The people who develop undergraduate engineering and education programmes at university level might be influenced by the knowledge of the greatest science- and technology-related problems and the way their students prioritise them. With this knowledge, engineers and teachers could be better equipped to produce environmentally and socially aware citizens. If students become aware of problems in the global context, this could influence their thinking and problem-solving skills to change the world for the better, because they are aware of the problems in the world.

The question now is: To what extent do people get the opportunity to learn about these scientific and technological problems in society? To what extent are these problems part of the science curriculum in schools and universities? For example, to what extent are these problems merged into both the engineering and education curricula at universities? Society can be a partner in the process of scientific research and discoveries, instead of being simply an uninformed, and occasionally offended, recipient (Carolan, 2006).

Why is this important for engineering students? Engineers are responsible for many advances in science and technology and they have developed many ways to make life more comfortable and better for humans. Unfortunately many of these developments have done a lot of harm to the environment. Many of the problems created by developments in science and technology can only be solved through research and developments in science and technology. Engineers have the power to influence society with inventions and advances in problem solving related to innovations in science and technology. Therefore much more time should be invested in developing a curriculum in higher education (such as universities) to make engineering students aware of the problems and the gaps where new ideas and research are needed. Engineering students can then use this scientific and technological knowledge productively and positively in the interest of society (Le Grange, Rochford, & Sass, 1996). When global science- and technology-related problems become more commonly known, it is easier to include these problems in discussions with the public. When engineers are faced with challenges related to scientific and technological problems, they would be better equipped to solve these problems if they could derive solutions from public discussions and from the science community.

Education students provide the foundation to develop people to become citizens in their country. All teachers should have an understanding of science and technology and this knowledge should be included in the curriculum of initial teacher education programmes. Teachers are constantly faced with global problems that their students might have in their specific environment. Teachers can assist in helping the students become well taught learners and responsible citizens (Anna & Maria, 2011). More female students are enrolled in education programmes than in engineering programs. This enables education students as research subjects to offer a great sample of women to test, compared to the engineering sample, which would be mostly men. This enables gender differences to be tested and compared in the study using the samples from the two different disciplines. Gender differences in science are very apparent (Liveri & Kaila, 2011). Education seems to attract more women and engineering seems to attract more men. The way the engineering curriculum is designed enables men to relate to the content of the curriculum more than woman (Bybee, 2008). Perhaps if the curriculum of engineering was adapted more to address the needs of society, more women would be attracted to this field. Le Grange, Rochford and Sass (1996) support this notion by saying a more balanced representation of the sexes in engineering education may come about only when fundamental change takes place in the way engineering is viewed in relation to society and the environment, and as a result, the way in which engineering is taught and practised.

Science and technology have become both the cause of and solution to current environmental problems (Beck, 1992). In the light of this background, it is evident that science and technology could play a key role in solving the problems that the engineering and technological industry has caused (Beck, 1992). Engineers need to become more aware of problems in society and how they can become involved in resolving them. According to Le Grange, Rochford and Sass (1996), engineers should become more environmentally and socially aware, show greater social accountability, move towards maintaining the sustainability of the environment, attract a wider group of people, and include humanities subjects into the engineering Science teaching intended to address issues of global sustainability should be incorporated into science curricula in schools and universities as a way of addressing global problems related to science and technology (Orr, 1990). The role of teachers and the school curriculum in promoting learners' scientific literacy cannot be over-emphasised. If the science curriculum includes problems that are relevant to students' lives, this motivates the students, because they can relate to the topics being discussed. As Bybee (2008) points out, scientific literacy could influence the way students think about global science and technology problems, because updated, relevant and current scientific literacy can influence future decision making.

1.6 Hypotheses

Five hypotheses are tested in this study. These five hypotheses test whether there are significant differences between samples with regard to their mean rankings score of individual items on the RLGPI as a whole. These hypothesis were tested on the following fourth year students at Stellenbosch University: education vs. engineering, female education vs. female engineering, male education vs. female education, male education vs. male engineering and male engineering vs. female engineering. The hypotheses are expounded fully in Chapter 3.

1.7 Clarification of terms

Science-technology-society (STS) is an interdisciplinary field of study that examines the influence and relationship between society's knowledge, science and technology. It aims to provide a new mechanism for open discussions on an informal basis and to build a human network that would in time resolve the new types of problems stemming from the application of science and technology. This society will also explore the opportunities arising from science and technology, and address how to remove the barriers to using science and technology to solve the problems facing humankind (Science and Technology in Society forum, 2016).

Engineering is the branch of science and technology concerned with the design, building and use of engines, machines, and structures. In this study engineering refers specifically to **civil engineering**, which deals with the design and construction of roads, bridges, canals, dams and buildings.

The meaning of **science- and technology-related global problems** is defined in the revised Le Grange Global Priorities Instrument (LGPI) presented in the Appendix.

The Le Grange Global Priorities Instrument (LGPI) is a 15-item rank-order scale modified and adapted from Bybee (1984) and Ndodana et al. (1994) and is used for measuring how science-and technology-related global problems are ranked in order of their perceived importance, presented in the Appendix, page 134-135.

The RLGPI is a best-worst scale used in this study and is presented in the Appendix, page 137-139. The development of this instrument is discussed in detail in Chapter 3.

1.8 LIMITATIONS OF THE STUDY

In this investigation data gathering was limited to convenient and accessible samples of fourth-year engineering and education students from Stellenbosch University.
With quantitative data research there are some weaknesses. Self-reported information obtained from questionnaires may be inaccurate or incomplete. The administration of a structured questionnaire creates an unnatural situation that may alienate respondents. Research methods are inflexible because the instruments cannot be modified once the study begins. Reduction of data to numbers might result in information getting lost. The correlations produced (e.g. gender) may mask or ignore underlying causes or realities. Errors in the selection of procedures for determining statistical significance can result in erroneous findings regarding the impact of the results.

The number of STS global problems investigated was limited to 12, even though some students may have perceived additional STS issues of major importance. The limitations of the research instrument and of the research method employed in this investigation are discussed in Chapter 5.

1.9 THE ASSUMPTIONS OF THE STUDY

The study assumes that the respondents are in an informed position to make comparisons in prioritising science- and technology-related global problems. It is also assumed that the fact that some of the students were English second-language speakers would not necessarily or appreciably affect the way science- and technology-related problems are prioritised.

1.10 RESEARCH APPROACH

The data were collected during scheduled periods of formal instruction by means of the RLGPI (Revised Le Grange Global Priorities Instrument), a 12-item instrument designed for use by science educators, undergraduate engineering students, undergraduate education students and secondary school pupils who are English first- or second-language speakers. The data collection was efficient, requiring a period of about 10 to 15 minutes as part of the normal schedule of the students' period of instruction.

The data were then analysed to determine any statistically significant difference in the statistics gathered from the surveys. Mean ranking scores were compared between attributes and groups using mixed model repeated measures ANOVA. For post hoc testing Fisher least significant difference (LSD) was used. The initial F-test of the ANOVA tests the hypothesis that the mean rankings are equal across all attributes. If this test is rejected, then specific pairwise comparisons are made between two attributes at a time to determine in more detail the differences between attributes. These pairwise comparisons are the so-called post-hoc tests. Analyses were conducted using Statistica 13.

1.11 Organisation of the remainder of the thesis

Chapter Two

This chapter discusses the theory of ranking priorities as a research framework. The chapter also reviews the relevant theories, principles and concepts underpinning global problems related to science and technology, and also reports on previous research findings.

Chapter Three

This chapter presents the research method, including a description of the samples, the measuring instrument and the method of data collection.

Chapter Four

The results and summary of the findings of the research are reported in this chapter.

Chapter Five

This chapter discusses the empirical research findings of the study.

Chapter Six

This chapter formulates and presents conclusions, makes recommendations and consider the implications of the study for further research.

1.12 Chapter summary

This introductory chapter states the research problem and clarifies its background and significance. The aims of the research and key terms have also been clarified, the assumptions of the study stated, and the limitations of the research mentioned.

The next chapter will review the relevant literature and present the theoretical framework for the thesis.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature relevant to the study. The chapter is divided into five sections. Section 2.2 reviews previous studies done on the prioritising of science- and technology-related global problems. Section 2.3 examines relevant literature on the theoretical basis for employing rank-order scales in educational research. Section 2.4 reviews the literature that serves as the theoretical basis for the inclusion of the different items on the RLGPI. Section 2.5 provides a summary of the chapter.

2.2 Previous research findings on prioritising of Science-Technology-Society (STS) global problems

This section first reviews previous studies on prioritising STS global problems relevant to science education, including studies on pre-service teachers. This is followed by a consideration of studies on the way that engineering students prioritise STS global problems.

STS movement, in science education, is an outlook on science education that emphasizes the teaching of scientific and technological developments in their cultural, economic, social and political contexts (Ware, 1992). In this view of science education, students are encouraged to engage in issues pertaining to the impact of science on everyday life and make responsible decisions about how to address such issues.

In 1984 Bybee used 262 science teachers from 41 different nations to create an instrument to determine their ranked priorities of science- and technology-related global problems. The top-ranked items reported in this study were in the main independently replicated by United States college students (n=216) also surveyed in 1983 and 1984 (Bybee & Najafi, 1986). The science educators surveyed ranked *Population growth* as the most important problem, perhaps because the students in Bybee's 1984 study had the education and experience to recognise that it compounds all other problems faced by humankind (Bybee & Mau, 1986). However, the US college students ranked *Population growth* in seventh place. It is important to remember that the US college students were samples of first world contexts, and the science educators came from both third world and first world contexts. Consequently, science teachers ranked population growth as a higher priority, since population densities are usually higher in third world contexts, and so *Population growth* might be a more pressing issue in such contexts along with *Human health and disease* (Neiderud, 2015). In countries with higher population densities, human health and infectious diseases are usually a bigger problem than in countries with a lower population count, because diseases can't spread as fast when people are located far from each other (Neiderud, 2015). Science teachers ranked *World hunger*, *Air quality, Water resources, War technology* and *Human health* as the most essential global problems to them (Bybee & Mau, 1986). US college students ranked *Air quality* in the first place, followed by *World hunger and food resources* and *War technology* (Bybee & Najafi, 1986). In both studies by Bybee and colleagues, science educators and US college students ranked *Mineral resources* in the last position. Even though scientists were aware of the unsustainable way mineral resources were being exploited, this information was not part of the general public's information at that time, and including this item in the survey instrument served the purpose of creating awareness of the problem (Mikesell , 1994). The studies mentioned were also conducted during a time when notions about consumption, resource depletion, environmental sustainability, growth and world carrying capacity had not become part of mainstream educational programmes and part of issues highlighted by the media in the United States (Robinson, Trojok, & Norwisz, 1997).

Ware (1992) made a valuable contribution to STS research in a study entitled 'The Education of Secondary Science Teachers in Developing Countries'. Her findings were that the STS methodology provides the potential for assisting science teachers to make their students more curious about science and more relevant to their lives. Another finding was that pre-service science teachers have to develop a greater understanding of content and pedagogy if they want to help their students change their attitudes towards scientific knowledge and take actions towards advancing environmental knowledge, with the goal of making their students becoming more science literate and more responsible voters on issues that affect the environmental future of their country. The pre-service teachers in general appeared to look at the environmental threats and/or problems from the point of view of how they affected them personally and not how the country as a whole was affected (Ware, 1992).

In another study Robinson, Trojok and Norwisz (1997) tested students in Katowice Province, Poland, which is known to have some of the most severe air pollution of any area in Europe and where the rate of asthma and other breathing disorders is the highest in Poland. They found *Air quality and the atmosphere* was ranked highest by everyone. These samples also ranked energy resources as the least important environmental problem, even though most heating and electricity in the province was generated from the combustion of coal – the major cause of air pollution and hazardous waste. Students in Poland gave the highest ranking to those problems which they had the most personal experience of and that directly affected their lives. Another example of how personal experience directly affects students' priorities is reported in a study by Holman (1993), where students in Switzerland did not think global warming was a problem, but students in the Netherlands, where barriers have already been constructed to keep out the sea, saw global warming as a high priority (Robinson, Trojok, & Norwisz, 1997). Students in Switzerland are not directly confronted with the challenges of global warming every day, whereas the results of global warming could have a direct impact on the lives of people in the Netherlands because of rising sea levels and the fact that the Netherlands is a coastal country with part of the country below sea level.

In a more recent study conducted in 2012 Mai, Halim, Yaseen and Meerah administer an STS questionnaire to a group of 465 students and 34 teachers from 15 schools in Sana'a city, Yemen. Based on the findings of the study they recommended that *Human health and disease*, *Water supplies*, *Air pollution*, and *Energy shortages* should be the most important problems to be incorporated into the physics curriculum in Yemen. When the mean scores of students and teachers were compared, the results showed high correlations on the rankings of items (Mai, Halim, Yaseen, & Meerah, 2012). This means that when students' and teachers' results were compared, there was a high correlation between the items ranked highest and lowest. Both teachers and students ranked *Human health and disease* as their highest priority as global science- and technology-related problems (Mai, Halim, Yaseen, & Meerah, 2012). This result could suggest that more attention should be given to the problems people are currently facing in Sana'a city by incorporating these kinds of problems into the school curriculum.

The implications of the findings of these studies for education are that the STS methodology has the potential to help teachers make the curriculum more relevant to students' lives. The STS methodology also has the potential to make current problems in the world relevant to students' knowledge. Findings of studies on engineering students will be discussed next.

In a study by Ndodana, Rochford and Fraser (1994) Bybee's STS scale was administered to a group of 129 undergraduate chemical engineering students at the University of Cape Town and to 76 science teachers in Cape Town. High inter-correlations were found among the two groups' mean ranked priorities on the scale as a whole. Among the top six global problems in 1984, five received consistently high overall prioritisation in 1994, namely *Population growth; World hunger* and *food resources; Human health and disease*; *Air quality and atmosphere;* and *Water resources.* These top-ranked items clearly relate to basic human needs for long-term survival and provide evidence to support the importance of relevant modern curricula in chemical engineering. The higher ranking of *hazardous substance* by the chemical engineering students indicates their awareness of this problem and its impact on human health. The mean ranking of *War technology* as a priority declined by seven places from earlier studies. This change in position might be attributed to the agreed strategic arms limitations between the former USSR and the USA, which did not seem to threaten the Republic of South Africa (Ndodana, Rochford, & Fraser, 1994).

In the study conducted two years later by Le Grange, Rochford and Sass (1996), the LGPI was administered simultaneously to 214 engineering students at the University of Cape Town and to 78 business/marketing students at the Peninsula Technikon. High correlations between these groups were found. However, regarding concern about *Extinction of species*, business/marketing females ranked it higher than their male counterparts did, and engineering males ranked air pollution higher than their female peers did. Males and females in both samples agreed on high prioritisation for the provision of *Mass housing* along with *Population growth, Fresh water supplies* and *Human health and disease.* As in the case of previous studies, top-ranked items relate to basic human needs for long-term survival and in this case also indicated the importance of the interdisciplinary approach of the humanities in both engineering and business curricula.

The implication of the findings of the studies on engineering students is that high-quality engineering education that is geared towards finding creative solutions to pertinent and pervasive problems remains crucial for the practice and development of relevant engineering for the benefit of the wider humanity. The importance of adding aspects of humanities education to engineering degree courses is also implied by these findings. Addressing problems that are deemed important for society should be a feature incorporated into engineering curricula.

2.3 The use of rank-order scales in educational research

In this study a rank-order scale was used to obtain survey responses. A rank-order scale is a comparative rating scale. When we require participants to make relative judgements, we use comparative rating scales, which is a type of ordinal scale. A rank-order scale gives respondents a set of items and asks them to put the items in some form of order or priority. The measure of 'order' can include such things as preference, importance, liking or effectiveness. The order is often a simple ordinal structure or could be done by indicating a relative position (Kumar, 2014).

Rank-order scales in science education research covering a large range of topics have been used successfully. For example, Swain, Monk and Johnson (2000) reported a striking consistency for 18 years in the rankings of the aims of practical work of science teachers in England on surveys conducted in 1979 and 1997. Abrahams and Saglam (2010) used a rank-order scale to investigate a total of 393 teachers' views (in van den Berg, 2012) of practical work in science education. Coefficients of concordance of the various rankings and their significance were calculated. The findings suggest that whilst there have been substantial changes in teachers' views about the use of practical work at Key Stages 4 and 5 (age 15–18) there have been no substantial changes at Key Stage 3 (age 11–14). It appears that changes to the assessment criteria and a growing desire amongst educational policy-makers to improve the image of science had an effect on how those in the teaching profession perceive the value and aims of practical work, particularly at Key Stages 4 and 5. In another study using rank-order scales, Michael and McFarland (2011) discovered the core principles of physiology for the use of developing a conceptual assessment instrument for medical students. After two sets of surveys had been analysed, five core principles were established which they used for the development of a conceptual assessment instrument in physiology.

In yet another study van den Berg (2012) used a rank-order scale to establish the perceived perceptions of students on the role of lecturers in online discussions. The findings indicated that lecturers play a very specific role, focusing on guidance and support, in online discussions. Furthermore, it was evident from the questionnaires that students have definite perceptions with regard to what the role of the lecturers as facilitators should be (van den Berg, 2012). As discussed earlier, rank-order scales have also been used in engineering education (see Ndodana, Rochford and Fraser 1994; Le Grange, Rochford & Sass 1996).

The studies referred to above provide evidence that rank-order scales have been used in survey research conducted in the field of science and engineering education for decades and have produced reliable and valid results. Le Grange (1996) points out that a ranking approach is often used in everyday life. For example, people rank music from their favourite to their least favourite; in beauty competitions women are ranked from the most beautiful to the least beautiful; in competitions like *Master Chef* people are ranked from best to worst relative to their cooking skills; athletes may be placed in the order in which they finish a race, and so on. However, a ranking scale conveys nothing about the scale of the differences between ranks; the space between ranks four and five, for example, may be very large, but between ranks nine and ten it may be very small. Le Grange (1996) describes how the ranking records the order or sequence, but that the size of the rank interval is usually unknown and unlikely to be equal. This is a potential weakness of rank-order scales and the statistical analyses that can be performed on data produced by such scales are limited to the use of non-parametric statistics.

Rank-order surveys may force respondents to differentiate between items that they may regard as equivalent. This means they might have to read and reread items, but still feel indecisive about their decision. According to Munson and McIntyre (1979), ranking items may take on average three times longer to respond to than answering rating questions. Respondents can also be influenced by the order of the items on the questionnaire. The order of the items could influence their decision and make them more likely to arrange the first item on the questionnaire as the most important item and the last item as least important. It is for these reasons that the LGPI was revised in 2016 into the RLGPI a best-worst scale to mitigate some of these shortcomings. The revision of the LGPI to become the RLGPI is discussed in Chapter 3.

It is important for ratings to be reliable; therefore people must have a clear understanding of the meanings of the points on the scale (Statistical Services Centre, 2001). Abeyasekera, Lawson-McDowall and Wilson (1999) suggest that where ranks are used, some effort should be put into finding out from the respondents how much better an item ranked 1st is than an item ranked 2nd, how much better the item ranked 2nd is from the item ranked 3rd, and so on. In other words, they suggest, some idea of the distance between successive ranks should be established. This will allow the numerical ranks to be transformed into meaningful scores. Ranking is often the preferred way to ascertain people's views, because scoring is a more unnatural and perhaps a less reliable method for the individual and groups (Abeyasekera, Lawson-McDowall, & Wilson, 1999). It is with this in mind that three qualitative questions were added to the instrument asking respondents to provide reasons for their three highest rankings, etc.

Le Grange (1996) suggests non-parametric statistical methods must be used to analyse the data, because *rank-order scales* are not equal-interval scales and data produced by *rank-order scales* are not normally distributed. Rochford (1997) introduces the idea that simple ranking survey scales can be concise, efficient and effective data-gathering instruments in the hands of beginner researchers. The advantage of using ordinal measurement is the ease of collation and categorisation (Kumar, 2014). Ranking scales give you an insight into what matters to your respondents. Each response to an item has an individual value, giving results that you can easily average and rank numerically. This can be valuable for gaining insight, as it gives a statistical breakdown of your sample's preferences based on what you need to know. If you are making decisions and have various options to choose from, data from a ranking scale might give you a clearer insight into how to satisfy your audience based on what is important to them, for instance, planning a curriculum (Kumar, 2014). This will be discussed in more detail in Chapter 3.

2.4 Theoretical basis for selection of the 12 RLGPI items

The basis for the inclusion of the 12 items was informed by studies done on the topic over the past three decades, the views of experts in the field, and the 17 sustainable development goals of the United Nations. The United Nations has identified 17 sustainable development goals that highlight the key problems to be focused on to transform the world (United Nations, 2016). These include goals such as no poverty, no hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions and partnerships to achieve the goals (United Nations, 2016). Many of these goals align with the 12 items on the RLGPI.

The importance and relevance of each one of the individual items on the RLGPI will be discussed below.

2.4.1 Population growth

Years ago predictions were made about the world population and how much it might increase over time. According to Martin’s (1996) research, the world population was 200 million in the year 1 AD and increased to 500 million towards 1650. In 1850 the population increased to 1 billion and more than doubled to 4 billion in 1975. In just 41 years the population has already increased to 7.4 billion in 2016. One of the biggest problems inhibiting welfare is the fact that the largest increases in population growth have occurred in the poorest of countries. Predictions are that by 2030 the world population will be 8.501 billion and by 2050 it will be 9.725 billion. In Africa alone a population of 4.387 billion by the year 2100 is predicted (United Nations Department of Economic and Social Affairs/Population Division, 2015).

The constant increase of the human population is taking a serious toll on the earth and all its natural resources. Over-population is a genuine threat. It is one of the main reasons why environmental issues have become increasingly pressing and the environmental crisis is deepening (Vitousek, Mooney, Lubchenc, & Melillo, 1997). Negative externalities in the environment are leading to a degradation of natural resources at a local and national level, contributing to growing global problems such as loss of biodiversity and global warming (Zhou, 2009). As the population grows, so the need for resources and space grows. As the need for human space grows, the space left for the natural 'wild' habitat shrinks, and therefore biodiversity decreases as well as space for any other wildlife (Zhou, 2009). Also, as the population grows, the welfare of humans decreases. The two arms of welfare can be divided into economic growth and population growth. For sustained improvement of welfare levels, economic growth has to increase and the population size has to shrink (Zhou, 2009).

One of the biggest problems associated with population growth is immigration (United Nations Environment Programme, 2014). Some countries become over-populated and this leads to work scarcity, because when the population grows faster than work can be created, there is a shortage of work supply (Fotso, Ezeh, Madise, & Ciera, 2007). People in this particular situation, as in third world countries, might be forced to flee to a first world country to seek a better life for themselves and their families. This could create many challenges for the people fleeing their own countries. It is not always easy to get legal approval when fleeing to another country. Many people have to move to another country illegally, because they have no other option. These undocumented refugees might face difficulties when they are confronted by the laws of the countries they enter, which require legal documentation. These refugees also have to live in very limited living spaces, because the current citizens of that country might only allow them minimum space. The flood of refugees moving from less developed countries to more developed countries impacts directly on the welfare of both the refugees and the citizens of that country. For example, Martins (1996) predicted that there might be a threat of the loss of European standards of life as the demographic and economic gap between the narrow strait connecting the Atlantic Ocean to the Mediterranean Sea widens. This means the competition for food and other resources increases, which in turn makes life harder for Europeans in general. We see this happening in countries such as Germany, France and Denmark, where thousands of refugees coming from Syria and other destabilised countries enter Europe seeking a better future, food, work and safety (Mannheimer, 2009). Refugees flooding into Europe from Africa, the Middle East and South Asia have presented European leaders with one of their greatest challenges. Despite the escalating human toll, the European Union's collective response to the influx has been to protect its borders and not protect the rights of migrants and refugees. This is because the threat of the refugee influx has many consequences for the countries being invaded in this way (Park, 2015).

The world produces enough food for all people living today, yet malnutrition is a major problem. Soon the space for agriculture will also run out if population growth continues along the current trend. It is quite simple: the earth has only a limited amount of land for all living organisms; when the human population increases, the space for all other organisms to live becomes less (Martins, 1996). When this takes place, there will also be less space for human agriculture. The resources for sustaining agriculture could also become constrained. This could lead to an increase in food prices (Park, 2015). When food becomes more expensive, fewer people can pay for it, and therefore more people go hungry (Martins, 1996).

According to research done by the IEA (International Energy Agency) (2015), with the increase in human population comes rising energy needs. Energy is vital in our everyday lives (International Energy Agency, 2015). Humans have become dependent on electricity and the services electricity can provide for us. Growing populations consume more energy (Dimick, 2014). Availability of energy allows populations to grow. Energy consumption exerts demands on energy resources, making them scarcer. Minerals from which energy is generated become harder to extract. Nearby forests are depleted, coal mines must dig deeper, oil has to be drilled in more complex environments (International Energy Agency, 2015). In other words, energy resource extraction experiences declining marginal returns, and the earth's carrying capacity is pushed to its limits (Darmstadter, 2004).

Energy use worldwide is set to grow by one third to 2040 (International Energy Agency, 2015). Additional investments have been required to increase the quantity of health, education and other services to meet the needs of the increasing population (Park, 2015). On a regional basis there is a relationship between population growth and growth of per capita income – where the one increases, the other decreases (Martins, 1996). This explains the growing population in developing countries and the shrinking population in developed countries, and might be one explanation for why there is migration from the developing to the developed world. For example; in India both population and income are on the rise and an additional 315 million people are anticipated to be living in India's cities by 2040 (International Energy Agency, 2015). Martins (1996) explains that adverse monetary externalities reduce the income of some groups (especially the poor) and this aggravates the problems of poverty and income inequality in developing countries.

Science and technology have been responsible for many of the solutions for the problems of population growth over the last century. Scientist in the medical field developed pills that can prevent a woman from becoming pregnant if she drinks one every day (Godfrey, 2016). Condoms have been developed that prevent the sperm from reaching the ova in a woman's ovary (Godfrey, 2016). Advances in science and technology have helped to develop many methods to avoid pregnancy such as birth control implant (Implanon and Nexplanon), birth control patch, birth control shot (Depo-Provera), birth control sponge (Today Sponge), birth control vaginal ring (NuvaRing), cervical cap (FemCap), diaphragm, IUD, morning-after pill (Plan B), spermicide, sterilisation for women (tubal sterilisation) and vasectomy (Godfrey, 2016).

2.4.2 Hazardous substances

Overfilled landfills are literally a growing problem. Landfilling is the easiest and generally preferred low-cost method for disposing of waste. In most low- to medium-income developing nations, almost all solid waste generated goes to landfills (Aljaradin & Persson, 2012). The available space for dumping the increasing amounts of waste humans are producing is decreasing. Even recycling isn't efficient enough to solve this problem.

Landfilling also has many effects on water resources (Aljaradin & Persson, 2012). The processes used to make many products involve the production of toxic waste as a by-product and this raises many problems, one of which is its disposal. Toxic waste and plastic waste are dumped in the oceans and rivers. Another unsustainable solution to waste disposal is burning it. This produces many toxic fumes that are released into the air, which only contributes to global warming even further:

> Landfills worldwide are estimated to produce 40 million metric tons of methane each year, which is approximately 7.5% of the methane produced and released each year into the earth's atmosphere by all natural and anthropogenic sources (Aljaradin & Persson, 2012, p. 29).

If humans do not start using alternative sustainable methods of disposing of waste, the problems associated with the production of waste will be exacerbated.

A so-called 'garbage patch' is a concentration of marine debris in the ocean. It consists mainly of plastic items with an estimated concentration of about 119139 pieces per square kilometres, according to the United Nations Environmental Programme approximations (UNEP, 2006). The largest garbage patch is referred to as the Great Pacific Garbage Patch. Too much plastic is disrupting the oceans (Sesini, 2011). Plastic is not biodegradable, it releases dangerous toxins, it affects ecosystems negatively, and it is a problem of global scale (Sesini, 2011).

As previously discussed, a growing population and economy mean increased volumes of waste generated. This puts pressure on waste-management facilities, which are already in short supply, according to the Department of Environmental Affairs in South Africa (2011). Waste streams are becoming more difficult to control and manage because of the expansion of urbanisation and industrialisation. The more complex the waste stream becomes, the more complex it is to manage, a problem which is compounded when hazardous waste mixes with general waste.

The South African Department of Environmental Affairs (2011), said that last year, 95% of urban households and 75% of rural households were to have access to adequate levels of waste removal. More and more focus is being placed on public education on the links between a clean environment, human health and sustainable development (Jasarevic, Thomas, & Osseiran, 2014). Monitoring and control of littering, burning of waste and uncontrolled salvaging of waste from landfill sites are among the leading problems for the government's control over hazardous substances. The National Department of Environmental Affairs is primarily mandated to regulate hazardous waste landfill sites, and the Provincial Departments of Environmental Affairs are mandated to regulate general waste landfill sites (Department of Environmental Affairs, 2011). Municipalities are responsible for the provision of waste-collection services as well as the monitoring and controlling of the illegal burning of waste and littering. There is a major problem of inadequate waste services for urban informal areas, tribal areas and rural formal areas (Department of Environmental Affairs, 2011). Although 61% of all South African households had access to kerbside domestic waste-collection services in 2007, this access remains tilted in favour of the more wealthy areas (Department of Environmental Affairs, 2011). Inadequate waste services lead to unpleasant living conditions and a polluted, unhealthy environment.

There is a growing pressure on outdated waste-management infrastructure, according to the Department of Environmental Affairs (2011). There is also little support for capital investment and maintenance. And this also contributes to one of the biggest problems facing waste removal and treatment services, namely that few waste treatment options are available to manage waste, because they are more expensive than landfill costs.

With help from science and technology the waste management of hazardous substances could be improved. Examples of this could be the development of techniques for the removal of radioisotopes from radioactive solutions by using activated carbon by means of both batch and column techniques (Omara & Moloukhia, 2008). Uranium is considered a hazardous substance when it comes into contact with humans, especially in water sources (Kütahyalı & Eral, 2004). With science and technology it has become possible to remove uranium from water sources. There involves using a method where activated carbon, prepared from charcoal by a chemical activation, selectively adsorbs uranium from aqueous solutions (Kütahyalı & Eral, 2004).

2.4.3 Human health and disease

Many people all over the world do not have access to adequate sanitation or waste-removal systems. In 2012 there were 863 million people living in unclean, overcrowded areas. Many factors such as natural disasters, warfare, poverty or overpopulation created the perfect breeding grounds for infectious and non-contagious diseases. These include diseases like influenza, malaria and the West Nile virus, which are carried by water, air, food, mosquitoes or rodents:

> Human infectious diseases are caused by pathogenic microorganisms such as bacteria, viruses, parasites and fungi that spread directly or indirectly via a vector from one person to another or from an animal to people. The 2004/5 Year Book reported that 15 million people died annually from infectious diseases, making them the world's leading cause of death and accounting for 25% of global mortality (United Nations Environment Programme, 2014).

Environmental disruption leads to the spread of new diseases, while unharmed, complete ecosystems have a defensive effect against contagious diseases. An approach to infectious disease control is maintaining a strong and healthy natural environment, with a strong immune system that protects people against the impact of contagious diseases (United Nations Environment Programme, 2014).

Human lifestyles and pressure from society cause problems such as mental health, stress, unbalanced diet, malnutrition and obesity. Because the food industry is focused on profit and speed, foods are processed and filled with sugar and other unhealthy addictive substances. Because so many people have office jobs, they spend little time outside. This could be responsible for the lack of exercise and inadequate physical activity, which contributes to people's health issues (World Health Organization, 2016). The constant noise from cars, building construction, human activities etc. makes living in peace and quiet very difficult and rare. The lack of a quiet environment contributes to increased stress levels and mental health issues (World Health Organization, 2016).

Malaria is one of the life-threatening diseases caused by parasites that are transmitted to people through the bite of infected female mosquitoes. About 3.2 billion people are at risk of malaria, but fortunately malaria outbreaks are predictable and the disease is curable. Between 2000 and 2015, the incidence of malaria among populations at risk fell by 37% globally (World Health Organization, 2016). Another disease that threatened society is Ebola, a viral haemorrhagic fever; it is a severe illness and is sometimes associated with high fever, bleeding and death (World Health Organization, 2016). Ebola killed more than 11,000 people since its outbreak in December 2013 (United Nations, 2016). Worldwide there have been 28,646 cases of Ebola virus disease and

11,323 deaths by 27 March 2016 (World Health Organization, 2016). Today, there are over 10,000 survivors of Ebola virus disease. The United Nations and similar organisations such as the World Health Organisation are working on plans to interrupt all remaining chains of Ebola transmission, to respond to the consequences of residual risks and to work on the recovery of health systems. They are also developing a vaccine against Ebola, but because Ebola is a virus, it is difficult to keep up with the virus mutations (United Nations, 2016).

One of the most serious epidemic diseases is HIV and AIDS. Here are some of the global statistics on HIV/AIDS, according to United Nations AIDS organisation (2015): 5.8 million people are accessing antiretroviral therapy (June 2015); 36.9 million people globally were living with HIV (end 2014); 2 million people became newly infected with HIV (end 2014); 1.2 million people died from AIDS-related illnesses (end 2014). Positive news is that new HIV infections have fallen by 35% since 2000 and AIDS-related deaths have fallen by 42% since the peak in 2004 (United Nations AIDS, 2015). Many organisations have started smaller programmes to educate the youth such as EDUCAIDS (Education on AIDS). EDUCAIDS has two primary goals: to utilise education to help prevent the spread of HIV, and to protect the core functions of the education system from the worst effects of the epidemic. In 2014-2015 the programme focused on new areas of work including: teacher training and sexuality education; school-related gender-based violence; and adolescent pregnancy and girls' rights to education.

With the latest research in science and technology, scientists have been able to determine the causes and the treatments for many diseases such as the Zika virus that is currently an epidemic in South America and surrounding islands. This virus is mainly transmitted by mosquitos, but recent research shows substantial evidence that now indicates that the Zika virus can be transmitted from the mother to the foetus during pregnancy (Petersen, Jamieson, Powers, & Honein, 2016). Only with the most recent advances in science and technology were they able to identify the Zika virus RNA in the amniotic fluid of mothers whose foetuses had cerebral abnormalities detected by ultrasonography, and to identify viral antigen and RNA in the brain tissue and placentas of children who were born with microcephaly and died soon after birth as well as in tissue from miscarriages (Petersen, Jamieson, Powers, & Honein, 2016). Advances in science are therefore able to help us understand the nature and causes of diseases better and how to overcome many diseases.

2.4.4 Fresh water supplies

Clean, drinkable fresh water resources are becoming less available. Water availability is expected to decrease even more in many regions as a consequence of climate change. Yet future global agricultural water consumption alone is estimated to increase by more than 19% by 2050 (Mekonnen & Hoekstra, 2011). Water for irrigation and food production creates one of the biggest stresses on freshwater resources. Agriculture accounts for more than 70% of global freshwater withdrawals (Hoekstra, 2008). Water is a renewable resource, but with the increased demand for it, its availability and state (liquid) are restricted (Pimentel et al., 1997). With the increase in population and technological advances, the need for water grows. Water is used in the production of most products in developed and developing countries. All ecosystems and natural systems are dependent on water. Without water, agriculture won't be possible. Humans and other animals need clean drinking water to survive (Gleick , 1996).

Gleick (1996) writes that the average human needs a minimum of 50 litres of water per day for various purposes. Gleick (1996) also writes that this water requirement will change depending on the climatic conditions, lifestyle, culture, tradition, diet, technology, wealth and distance from the water source. All humans have the right to clean drinkable water in the right quantities to sustain their lifestyle. This notion was supported during the 1992 Earth Summit in Rio de Janeiro (Gleick , 1996).

Another growing problem is gas fracking: "Fracking refers to hydraulic fracturing- a process where a high-pressure fluid mixture is released into drilled channels in the earth to increase fractures in rocks" (Van der Merwe, 2013, p. 1). These fractures set gas and oil free. The fluid mixture consists of water, sand and chemicals (Darmstadter, 2004). As these fractures get bigger, the gas and oil that flows into the wellbore from which it is extracted, increases (Van der Merwe, 2013). The method is used to either make new pathways to release gas or to enlarge existing pathways. The South African government is supporting the process of natural gas extraction as the solution to the current energy crisis (Van der Merwe, 2013). However, the government acknowledge coal's downsides- it is an unsustainable resource and the process whereby it is converted into electrical energy is far worse for the environment than natural gas. Fracking also needs copious amounts of water and the targeted area in South Africa is the Karoo, which is already a water scarce area (Van der Merwe, 2013). According to the Treasure Karoo Action Group, fracking requires around 20 million litres of fresh water per well, each pad can have up to 32 wells (Van der Merwe, 2013). During the fracking process there is the risk of polluting the groundwater with chemical spills or cracked well casings (Van der Merwe, 2013). Furthermore, the water flowing back to the surface is toxic. Other underground rivers like these are being polluted and so are other natural water sources, reducing water available for human and animal consumption (Darmstadter, 2004). Nitrogen used in agriculture also poses a threat for fresh water sources:

> Nitrogen is used to increase food production, because it is vital to plant growth. But, excess nitrogen in the environment contributes to health and environmental problems such as groundwater pollution by nitrates and freshwater pollution due to eutrophication and acidification (United Nations Environment Programme, 2014, p. 7).

The chemicals used to control and kill weeds and pests pollute the soil and underground water systems. As these chemicals spread through the natural water cycle, rivers are poisoned. Eutrophication is a big problem, because it also leads to acidification and a decline in the ocean's biodiversity:

> Organisms require oxygen to grow and reproduce. 'Dead zones' are oxygen-depleted (hypoxic) areas that result from over-enrichment of waters with nutrients (especially nitrogen and phosphorus), for example from fertiliser run-off, industrial waste and sewage. Reported cases of coastal dead zones have doubled in each of the last four decades. There are currently over 500 known dead zones in the world, whereas in 2003 only around 150 such oxygen-depleted areas were reported. Close to 1000 other coastal and marine areas are experiencing the effects of eutrophication (United Nations Environment Programme, 2014).

Water pollution and loss of species as a result of toxic herbicides and pesticides remain a big problem. Because farming is based on profit and money, the time dedicated to farming practices has to be short and effective. Herbicides and pesticides are used, because removing weeds and killing pests with natural and organic methods is too time consuming. Farming the organic way doesn't create as much profit as conventional monoculture farming methods do. Genetic engineering is used to develop herbicide-resistant crops, but this has led to the creation of many weeds that have become genetically resistant to the current herbicides (United Nations Environment Programme, 2014), which in turn led to the development of even more genetic engineering and toxic herbicides. The development of more toxic and stronger herbicides is causing even more water and soil pollution (United Nations Environment Programme, 2014).

As things like global warming, the over-use of water by industries, population growth and water pollution increase, the total amount of available drinking water decreases. In many sub-Saharan countries public support schemes that benefited agriculture and rural development were downscaled or abandoned (Fotso, Ezeh, Madise, & Ciera, 2007). This process resulted in increased migration flows from rural to urban areas. In turn this lead to a greater pressure on nearby water resources such as rivers and lakes. Because of the lack of infrastructure for proper public sewage systems, the increased human population used some of these rivers as their only means of sewage removal (Fotso, Ezeh, Madise, & Ciera, 2007).

On top of the increased water consumption that comes with population growth comes the increased use of water for agriculture (Pimentel et al., 1997). Economic growth, Westernisation and increased individual wealth are responsible for shifting diets from being mainly starch-based to meat and dairy-based ones. This has an immense impact on the consumption of water. Producing 1 kg of rice, for example, requires about 3,500 litres of water, 1 kg of beef about 15,000 litres, and a cup of coffee about 140 litres (Hoekstra, 2008). This dietary shift is the most significant factor behind the increase in water consumption over the past 30 years and is likely to continue to be the biggest growing problem (Mekonnen & Hoekstra, 2011).

Even more proof of the large amount of water set for the production of beef is provided by Beckett and Oltjen (2015) with these statistics: "…the United States beef cattle herd produced 6.9 billion kg of boneless beef. Beef cattle directly consumed 760 billion litres of water per year…" and also "The model estimates 3682 litres of developed water per kilogram of boneless meat for beef cattle production in the United States." It is estimated that the average milk cow drinks about 200 litres of water per day (Beckett & Oltjen, 2015). Only when we compare this amount of water with the average amount of 2 litres of water the average human consumes per day can we understand the magnitude of the impact on water supplies.

In South Africa water quality is a matter of concern. This is one of the most important reasons why there is a water shortage, because water is not drinkable. For example, the Olifants River is one of the most important rivers flowing through the eastern provinces of South Africa. Coal mines located alongside the river are dumping their waste into the river; these mines are partly responsible for the pollution of the river (Nieuwoudt & Backeberg, 2011).

Waste from factories and power plants is dumped into the oceans and rivers. "It's like a toilet bowl that never flushes", said Anna Cummins, education adviser at the Algalita Marine Research Foundation in Long Beach, California. Through developments and research in science and technology we were able to determine the impact of pollutants such as waste and pesticides on water sources. Water pollution and loss of species as a result of toxic herbicides and pesticides remain a big problem.

South Africa's farming industry is currently under threat from the drought that the country is facing. "The ability of South African farmers to continue producing at the levels needed to maintain national food security is threatened by the high probability of a second consequent year of drought across many regions", said Agri SA president Johannes Möller in November, 2016. In the regions such as North West, Free State and KwaZulu-Natal provinces farmers are exposed to severe financial losses (because of the drought), which have made it very difficult for them to survive as successful businesses and to pay what they owe to the financial institutions (Möller, 2016). These financial institutions may then limit production credit for the coming season, which means that in the season to come farmers will suffer financially in addition to having to cope with limited water resources. These factors would result in lower crop production, labour shedding and rising food prices (Möller, 2016). Many farmers are resorting to solutions that only science and technology can provide, such as improved use of bore holes, which enables farmers to use the underground water system (Möller, 2016). Developing alternative farming methods and alternative crops that are less water intensive are also ways in which research in science can help farmers (Möller, 2016).

2.4.5 Loss of biodiversity

One of the major problems facing humanity is the loss of biodiversity. Humans need diversity in nature for survival. Biodiversity is being lost through the harvesting of resources such as oil, wood and fish. Not only is oil drilling causing pollution, but oil resources are running out and natural habitats are being destroyed in search for more oil sources (United Nations Environment Programme, 2014). Wood is used for the manufacturing of toilet paper, paper, furniture, houses etc. As the human population grows, so the need for wood is growing as well. Forests are also cut down for many other reasons, but one of the biggest reasons is to allow for more grazing space for cattle (Pimentel et al., 1997). Ships catching fish in large amounts means that the industry is unsustainable and the natural resource and diversity of fish stocks will soon disappear if fishing methods don't become more sustainable. As Gonthier (2014) said:

> Despite knowing about biodiversity's importance for a long time, human activity has been causing massive extinctions in both animal and plant species. According to the UN's 3rd Global Biodiversity Outlook, things that make out the loss of biodiversity include habitat loss and degradation, climate change, excessive nutrient load and other forms of pollution, over-exploitation and unsustainable use and invasive alien species. The main cause of biodiversity loss is human population growth and the increasing activity of agriculture that goes with it.

Agriculture has led to the transformation of natural habitats to croplands, immense diversion of water from lakes, rivers and underground aquifers and, at the same time, has polluted water and land resources with pesticides, fertilisers, and animal wastes (Gonthier et al., 2014).

The effect of the growing human population on the loss of biodiversity has created a need for more wood, living space and agriculture. Agriculture has become incorporated into the global economy. This has led to increased stress on agricultural land for exports and exchange produce. More land is being diverted from local food production to "money crops" for export and exchange; fewer kinds of crops are raised and each crop is grown as large scale mono-crops (Secretariat of the Convention on Biological Diversity, 2014).

The spreading of deserts is also a growing global concern and has an impact on biodiversity, as many semi-arid and arid areas are being over-used by agricultural systems and livestock grazing. With desertification comes the loss of biodiversity and extinction. Many natural river systems and springs are being used for agriculture or for the developments of urban living areas. When rivers and dams dry out, because of water being over-used, desertification also takes place, leading to further loss of biodiversity (Secretariat of the Convention on Biological Diversity, 2014).

Overfishing is primarily the result of excessive fishing by industrial fishing fleets. Aquaculture is consequently the fastest growing animal-based food producing sector, particularly in developing countries. Over-exploitation occurs when fish and other living resources are caught at a rate that exceeds the maximum harvest that allows the population to be maintained by reproduction (United Nations Environmental Programme, 2006).

The poaching of animals is a growing concern. Basic economic principles of supply and demand ensure that as animals get closer to becoming extinct, the higher the market value of that animal (O'Donoghue & Rutz, 2016). Anti-poaching rangers protecting these animals usually only show up at the crime scene after the animal has been killed, making poaching a low-risk, high-gains enterprise (O'Donoghue & Rutz, 2016). With the help of science and technology, cutting-edge tracking technology could be fitted to high-risk animals to keep track of any poaching event to make it easier for the rangers to find the poachers and capture them (O'Donoghue & Rutz, 2016). Through science and technology this innovative approach could assist in the fight against wildlife crime.

2.4.6 Energy shortages

Energy use is directly linked to development and progress:

> [As] income per capita rises, so does per capita energy use. The reason is evident. Energy – electricity to run motors, fuels for transport, and hundreds of other applications – is a vital complement to other investments for boosting productivity and stimulating economic growth. In turn, that very growth gives rise to

acquisition of household necessities and creature comforts associated with increased energy usage (Darmstadter, 2004, p. 1).

All countries are striving for development and better lives, therefore this development is inevitable and so is the rise in the demand for energy. The fact that energy needs will continue to grow means that current energy sources will be over-used and alternative sustainable forms of energy have to be developed and used.

"To conserve our environmental heritage and natural resources for future generations, economically viable solutions must be developed to reduce resource consumption, stop pollution and conserve natural habitats" (United Nations, 2002, p. 1). Humans are using up natural resources that the planet provides at an alarming rate. Because of the growing need for energy and fuels, energy resources (as previously discussed) such as coal, wood and fossil fuels are being used up to the point where resources are almost exhausted. If humans can't lower their use of energy, alternative methods of generating energy will have to be developed and implemented as soon as possible. Unfortunately humans rely mainly on fossil fuels for the production of electricity (International Energy Agency, 2015). Fossil fuels are limited and will eventually be depleted. Thus, humans will be forced to find alternative methods of producing electricity that are sustainable.

Alternative lower-carbon fuels, such as gas, and technologies will be used in many European countries and a 15% decline in energy use is predicted by 2040 (International Energy Agency, 2015). It is estimated that 1.7 billion people (17% of the global population) remain without electricity; the IEA (2015) predicts that by 2030 the number of people without electricity will fall to 800 million. By 2030, in India alone, there will be 900 million more people who require electricity. Fortunately there is a trend of moving towards renewable energy sources in the future. Policy preferences for lower-carbon energy options are reinforced by trends in costs, as oil and gas become progressively more expensive to extract, while the costs of renewables and of more efficient end-use technologies continue to fall (International Energy Agency, 2015).

In South Africa there are many challenges amid the climate change crisis of the 21st century. South Africa is both cursed and blessed with an abundance of coal; it could be be beneficial for cheap electricity, but it is against the principles of sustainable energy use (Tshehla, 2014). There is a lack of knowledge in the government and municipalities about how to solve the energy crisis with sustainable solutions that are fit for the future (Tshehla, 2014). The Department of Minerals and Energy's White Paper on Renewable Energy (2003) states that "we intend to give much needed thrust to renewable energy". This direction was manifested in a target of 10,000 GWh renewable energy contribution to final energy consumption by 2013 (Department of Minerals and Energy, 2003). This White Paper also states that "ensuring that an equitable level of national resources is invested in renewable technologies, given their potential and compared to investments in other energy supply options" (Department of Minerals and Energy, 2003). Despite the White Paper being produced a decade ago and recognising the potential of RETs (Renewable Energy Technologies) in comparison to conventional technologies, it was only after the 2007/2008 electricity shortages that the government made significant moves to facilitate the growth of RETs through the REIPPP (Renewable Energy Independent Power Producer Procurement Programme) (Tshehla, 2014). The current solutions by an over-politicised energy sector are to build more diesel-, coal- and gas-fired power plants (Hedden, 2015). Future energy solutions extending to 2020 are largely expected to come from the Medupi and Kusile coal-fired power plants still under construction (Hedden, 2015). Wind and solar power are to be added consistently, generating power of 8.4 Giga Watts (GW) each by 2030 (Hedden, 2015). The first nuclear power station to be built should come online in 2023 and the power generated increases by 1.6 GW in five of the following six years, totalling 9.6 GW by 2030. In addition, 3.3 GW of hydropower is imported from Mozambique and Zambia (Hedden, 2015). Many power plants need to be decommissioned in 2022, because of the lack of maintenance by the government services running these stations (Hedden, 2015). By 2030 total installed capacity will double from 44.5 GW to 9.5 GW; 29% will be coal-powered; 17% will be nuclear; 16.3% will be wind; and 14.9% will be solar PV (Hedden, 2015).

2.4.7 War technology

There were 80 per cent more deaths from terrorism attacks in 2014 than in 2013 (Institute for Economics and Peace, 2015). This is the biggest annual rise in total deaths from terrorist attacks in the last 15 years. "Since the beginning of the 21st century, there has been more than a nine-fold increase in the number of deaths from terrorism, rising from 3,329 in 2000 to 32,685 in 2014" (Institute for Economics and Peace, 2015). The five countries in which terrorist activity seems to be the highest are Iraq, Nigeria, Afghanistan, Pakistan and Syria. In 2014, 78 per cent of the total deaths occurred in these countries.

> Although highly concentrated, terrorism is spreading to more countries, with the number of countries experiencing more than 500 deaths increasing from five to eleven, a 120 per cent increase from the previous year. The six new countries with over 500 deaths are Somalia, Ukraine, Yemen, Central African Republic, South Sudan and Cameroon (Institute for Economics and Peace, 2015, p. 1).

As previously discussed, when welfare declines in a country, the number of people leaving the country seems to increase. Terrorism activity in a state or country is one reason for displaced and fleeing populations. The Syrian conflict has on its own led to four million people moving beyond its borders, with another seven million people internally displaced (Institute for Economics and Peace, 2015). As previously discussed, these refugees present major challenges for the countries being invaded by immigrants.

The financial implications of terrorist activities are also greater than before. As the terrorist attacks increase, the money spent on war technology and restoration increases. Two factors associated with terrorism include political violence committed by the government and the wider presence of war (Institute for Economics and Peace, 2015).

> When analysing the correlates of terrorism between wealthier and poorer countries, different factors were found to be statistically significant. In the richer OECD countries, socio-economic factors such as youth unemployment, confidence in the press, belief in democracy, drug crime and attitudes towards immigration are the most statistically significant factors correlating with terrorism (Institute for Economics and Peace, 2015, p. 3).

In poorer non-OECD countries factors such as a history of armed conflict, conflict inside the country (that has been going on for many years), corruption within the government and a bad business environment contributed towards making the country a breeding ground for terrorism (Institute for Economics and Peace, 2015).

In recent decades we have witnessed the use of a range of more unconventional war technologies such as biological/chemical weapons:

> Chemical weapons are defined as non-living, manufactured chemical agents combined with a dispersal mechanism that, when activated, produce incapacitating, damaging or lethal effects on human beings, animals or plants (Immenkamp, 2015, p. 2).

According to Immenkamp (2015), biological weapons come in different forms, such as gas, solid or liquid, and are absorbed through breathing, eating or absorption by the skin:

"Several experts have warned that there is a genuine risk of ISIL/Da'esh using chemical, biological, radiological or even nuclear materials in the context of future attacks on European targets" (Bar-Yaacov, 2015, p. 1). This is becoming a real global problem, because threats are being distributed to more countries especially in Europe, where millions of people live in close proximity to one another. ISIL/Da'esh is the self-proclaimed 'Islamic State' in Iraq. They are currently one of the biggest threats to Europe as well as other Islamic countries. According to Bar- Yaacov (2015), their next weapon of choice could be a self-made biological bomb made from chemical or radioactive ingredients.

> Since the beginning of October, terrorist attacks in Ankara, the Sinai Peninsula, Beirut Paris and Tunis, for which ISIL/Da'esh has claimed responsibility, have cost the lives of 500 people. The attackers' weapons of choice so far have been explosive devices, including car bombs and suicide belts, and automatic weapons. Immediately following the attacks in Paris on 13 November, the group announced that further attacks would take place in the immediate future, in Paris and other capital cities. Washington DC, London, and Rome were specifically mentioned, as well as targets in Belgium (Immenkamp, 2015, p. 2).

These attacks could become serious priorities for people living in that region or who are affected by the events in that area and this could have a global effect.

According to research done by Bar-Yaacov in 2015, there have been several instances of biological warfare attacks by ISIL/Da'esh. They have used chemical weapons in Syria and Iraq at least three times during June and July 2015. Also, in June 2015, the Australian Foreign Minister, Julie Bishop, said that ISIL/Da'esh might have used chlorine in a previous attack. This is a matter of grave concern; as chemical war technology develops further, terrorists become more ruthless and this creates a global issue that has implications for everyone.

Nuclear weapons are one of the main problems regarding war technology. Many countries like Iraq, North Korea and Syria are in possession of illegal nuclear weapons. This creates the problem that everyone is in danger, because unexpected and uncontrolled nuclear attacks could have disastrous effects on cities, homes and even on farm land. The radioactive consequences of the use of nuclear weapons leave a lasting destructive effect on the environment and on future generations. Radioactive materials could cause cancer, mutations, hazardous waste, water pollution and death. The United States of America undertook some missions that involved removing radioactive sources and nuclear waste from previous Iraq wars and dismantled after the second Gulf war. The clear aim of these efforts was to reduce the risk of terrorists acquiring these dangerous nuclear materials, but there might be dangerous nuclear materials that are still left in Iraqi territory (Rudischhauser, 2015).

War technology provides an example of how science and technology could be used negatively and have disastrous effects on the natural environment, but they can also provide the solution. With the right methods applied through science and technology, radioactive sources can be cleaned and removed, even though the radioactive material was created by developments in science and technology in the first place. Through developments in science, quantum chemistry contributed to one of the most important scientific achievements of last century (Lanjewar, 2015). Quantum chemistry and other scientific fields contributed to the treatment and disposal of the contents of radioactive tanks; this content can be separated into high-level waste (HLW) and low-level waste (LLW) fractions (McGinnis, Welch, & Hunt, 1999). Since the unit costs of treatment and disposal are considerably higher for HLW than for LLW, technologies to decrease the amount of HLW are being developed. A key process currently being studied to reduce the volume of HLW sludge is called enhanced sludge washing (ESW) (McGinnis, Welch, & Hunt, 1999).

As we give our work to the machine and the machine comes to relieve the stress of our being vulnerable to nature, we are rendered increasingly dependent on the machine and to the technology we created (Coeckelbergh, 2015). This creates the paradox that humans desire to become less vulnerable to and more independent from nature, but the very tools used for this purpose are creating new vulnerabilities and dependencies (Coeckelbergh, 2015). Over the last decade "drone wars" have been subject to much debate and commentary, and a "new" mode of organised violence might become the mobilisation of police power; drones are first and foremost technologies of policing (Wall, 2016). Police power as broadly stated policy is concerned with dealing with the threats of intrusion to private property (Wall, 2016). Drones project power by occupying the skies and surveying populations (Wall, 2016). Citizens become vulnerable to the machines created (drones), and drones enforce the idea of power by violently intervening in the lives of earthly subjects (Wall, 2016). In Syria in 2016 there was another example of air-force misuse of drones when innocent civilians were killed and injured after a US air strike "mistake" (Economist Intelligence Unit N.A, 2016). It is known that the US has used armed drones in Iraq, Afghanistan, Pakistan, Yemen, Somalia, Libya and Syria; there have been unconfirmed reports of US drone strikes in Mali and the Philippines, and in 2015 UK armed forces carried out the targeted killing of British citizen, Reyaad Khan, in Syria using a Reaper drone (Cole, 2015). The stated aim of military action is to create long-term peace and security (Cole, 2015). Increasingly however there is a growing understanding that the use of armed drones may be doing just the opposite (Cole, 2015). Kurt Volker said recently: "Drone strikes allow our opponents to cast our country as a distant, high-tech, amoral purveyor of death. It builds resentment, facilitates terrorist recruitment and alienates those we should seek to inspire" (Cole, 2015, p. 2). Technologies developed for drone wars are used in the fight against terrorist organisations, but they do not solve our terrorist problem (Cole, 2015); in fact, drone use may prolong it (Cole, 2015). Therefore we can assume that the use of drones may put more lives at risk. This is another example of where technology was supposed to solve a problem, but created a bigger problem instead.

2.4.8 Air pollution

A wide spectrum of severe and chronic health impacts is associated with air pollution. Six pollutants commonly found in the air are: particulate matter, ground-level ozone, carbon monoxide, nitrogen oxides, sulphur oxides and lead. Of these contaminators, those that can generally pass through the human respiratory pathways and enter the lungs and bloodstream are the biggest concern. Once inhaled, they can cause acute health damage, including lung cancer and other cardiopulmonary damage; 3.7 million premature deaths worldwide were attributable to ambient air pollution (David & Gao, 2016).

Sources of air pollution include traffic (especially diesel vehicles), industrial sectors (from brick making to oil and gas production), power plants, cooking and heating with solid fuels (e.g. coal, wood, crop waste), forest fires and open burning of municipal waste and agricultural residues (United Nations Environment Programme, 2014). In some countries like China air pollution has become a major concern in cities such as Beijing, Shanghai and the Pearl River Delta region including Guangzhou, Shenzhen and Hong Kong (Chan & Yaoa, 2008). The situation in cities like these has become so serious that people have to wear protective masks to filter the air just to breathe clean air. Many are suffering from air-borne diseases such as asthma and upper respiratory tract infections because of the severe pollution. Air pollution is recognised as a very serious health hazard. Factories and other industries need to reduce their carbon and other greenhouse gas emissions to ensure the wellbeing of the world population at present and in the future. Governments need to monitor emissions, impose strict standards for total release into the atmosphere and investigate air quality. Moreover, activist organisations need to carry on fighting for clean air and more people need to be involved. There are some areas in South Africa where the air-quality standards are currently not very good. These areas include the Highveld and the Waterberge (Peden, 2006). Immediate changes in emissions need to be adopted or people in those regions will suffer serious consequences from the poor air quality. Greenhouse gas emissions are without question the main contributor to climate change (Jasarevic, Thomas, & Osseiran, 2014). In Africa a rise of over 4 degrees Celsius caused by greenhouse gas emissions in predicted by 2100 (Jasarevic, Thomas, & Osseiran, 2014).

> Forests play an integral role in mitigating climate change as carbon sinks – storing more carbon than both the atmosphere and the world's oil reserves. They also remove carbon from the atmosphere through photosynthesis, which converts atmospheric carbon to organic matter. While forests work diligently to clean up

> carbon emissions from burning fossil fuels, humans exacerbate the problem through deforestation by pumping carbon right back into the atmosphere (United Nations Environmental Programme, 2012, p. 1).

Economic progress needs energy sources such as coal, oil and firewood. But these methods of extracting energy are big emitters of carbon dioxide, contributing to air pollution and global warming (Siddiqi, 2008). "Each year the chemical industry produces more than 100 million tons of organic chemicals representing some 70,000 different compounds, with about 1,000 new ones being added each year" (Vitousek, Mooney, Lubchenc, & Melillo, 1997, p. 498).

As previously discussed, the impact of agriculture and livestock agriculture on the environment is undeniable. They are another major contributor to air pollution through methane emissions. The food we eat has the greatest impact on the amount of air pollution we generate. "Rice paddies are a major source of methane emissions, and rice is the principal staple food in Asia. Cattle and organic wastes are also significant contributors to methane emissions in Asia" (Siddiqi, 2008). Therefore, some solutions might be better control over our diet, which gives us the power to lower our carbon and methane emissions.

Pollution in industrial areas pose the biggest direct threat to humans (Jasarevic, Thomas, & Osseiran, 2014). The pollution from factories and power plants does not only cause air pollution, but also water and soil pollution. Air pollution and global warming contribute to acidification, which in its turn leads to coral bleaching and the decline in phytoplankton. Phytoplankton plays a major role in the absorption of carbon out of the atmosphere, which fights against air pollution and global warming (Nicol, Bowie, Jarman, Lannuzel, Meiners, van der Merwe, 2010). Recent scientific research has discovered the role of Baleen whales in the fertilisation of phytoplankton with the large amount of iron in their faeces (Nicol et al., 2010). Thus, allowing the great whales to recover might actually increase the overall productivity of the Southern Ocean to fight against air pollution (Nicol et al., 2010).

"We underline that climate change is one of the greatest challenges of our time" (United Nations, 2009, p. 1). Since climate change dominates the current transformation of the Arctic environment, reducing global greenhouse gas emissions is the most important action that needs to be taken. “Permafrost is a layer of frozen soil at some depth below the surface, where the temperature has continuously been below zero degrees Celsius” (United Nations Environment Programme, 2014, p. 2). It has been receding northwards in the Arctic as global temperatures rise. Enormous amounts of carbon are held within these layers of the Permafrost soil and, as these soils melt, carbon dioxide and methane gas will be released into the atmosphere, contributing to global warming and climate change (United Nations Environment Programme, 2014).

Nitrogen production is contributing to air pollution and is responsible for the depletion of stratospheric ozone, which protects life on Earth from harmful ultraviolet (UV) rays. Surplus nitrogen in the environment is used for fossil fuel combustion in transport and in energy production. This creates nitrogen oxides that also contribute to the negative effects on the environment (United Nations Environment Programme, 2014).

Methane is released in dangerous amounts through livestock agriculture. Cows and other animals release methane gas through the process of digestion. This gas is one of the gases responsible for global warming and climate change. “Agriculture’s contribution as a whole to global warming is estimated at between 18% and 20%, which according to some sources is higher than that of transportation” (Rust & Rust, 2013, p. 255). Current agricultural methods need to be revised and more sustainable and harmless methods need to be developed and used in the production of food. People’s diet and choice of food are among the biggest problems. Vegetarian and vegan diets are more environmentally friendly and the carbon footprint is much lower than that of a diet containing animal-derived products.

Research done by Rust (2013) found that the livestock industry accounts for around 5% to 10% of the overall agricultural contribution to global warming. Meat consumption is increasing all over the world. The meat industry can cause major scientific and technological problems (overgrazing, methane gas, livestock waste management, deforestation for grazing space, and habitat loss to provide feed for livestock) in the light of population growth and the lack of grazing space.

The role of science and technology is very important when it comes to dealing with the problem of air pollution. Accurate real-time monitoring of atmospheric conditions at ground level is vital for hazard warnings, meteorological forecasting, and the various environmental applications required for public health and safety (David & Gao, 2016). Existing tools for inversion monitoring are based on limited in situ measurements or remote sensing observations (David & Gao, 2016). Science and technology enabled the development of a new technique, which is based on utilising standard signal measurements from an existing cellular network during routine operations (David & Gao, 2016). This technique has the potential for identifying atmospheric conditions prone to air pollution by detecting temperature inversions that trap pollutants at ground level (David & Gao, 2016). Another way new technologies are fighting air pollution is through processes such as 'gasification' (turning coal into a gas and removing impurities from the coal gas before it is combusted) and a process called 'carbon capture and storage' (capturing the carbon dioxide from the fuel gas and storing it underground or reusing it (Miller, 2011)). Both of these techniques can be used in cleaning polluted air from coal-fired power plants (Miller, 2011).

2.4.8.1 Electromagnetic wave radiation

Electromagnetic wave radiation is becoming an increasingly big problem (Lucas, McMichael , Smith , & Armstrong , 2006) for the health of humans and the planet. Human exposure to solar ultraviolet radiation has important public health implications. Evidence of harm associated with overexposure to UV has been demonstrated in many studies (Lucas, McMichael , Smith , & Armstrong , 2006). The following statistics were produced by Lucas, McMichael, Smith and Armstrong (2006, p. 20) from a study they did on the global effects of UV light:

> A moderate degree of UV exposure is necessary for the production of Vitamin D, which is essential for bone health. Globally, excessive solar UVR exposure caused the loss of approximately 1.5 million DALYs (0.1% of the total global burden of disease) and 60 000 premature deaths in the year 2000.

Skin cancer and malignant melanomas are among the most severe health effects, but many other health risks have also become known. The most common effects of exposure to UV range from UVR-induced cortical cataracts, cutaneous malignant melanoma to sunburn. If humans avoid UVR exposure completely, illness would not be completely avoided, but the results would rather show a high chance of vitamin D deficiency.

In the meantime, our industrialised society is responsible for producing chlorofluorocarbons (CFCs) that react on a chemical level with the stratospheric ozone which protects the earth from most of the damaging wavelengths of UVR (Lucas, McMichael, Smith & Armstrong , 2006). The decline in stratospheric ozone is responsible for the growing levels of ultraviolet radiation on earth's surface. And this in turn contributes to the dangers of UVR and global warming.

2.4.9 World hunger and food resources

Thousands of South Africans and people all around the world are hungry and malnourished. Malnutrition and hunger have an influence on wellbeing, learning ability and overall happiness (Le Grange, 1996). Poor wealth distribution is a major cause of poverty. People doing labour-intensive jobs sometimes receive only a small portion of the profit and most of the time the owners of big companies take almost all of the profits (Cowell & Kerm, 2015). There are many situations like these where governments and big businesses distribute money unfairly and the ones being cheated are powerless (Cowell & Kerm, 2015).

Another major contributor to poverty is work shortages and lack of employment. Without work, people can't earn money. Many governments are being run poorly and they don't provide enough opportunities for creating jobs. Usually the population grows faster than the number of jobs the government can create (Martins, 1996). This causes more people to be without work and in turn results in more people without money to buy food.

Another reason for poverty is a climate unfit for farming. Individuals and communities are at risk because of the stress on their lives caused by the impacts of environmental change (Adger, 1999). For example, too little rain might be the cause of crop failure, while too much rain could be the cause of crops being flooded. In the bigger picture modern society is responsible for climate change having an impact on the poor (Dessler & Parson, 2006). Poverty and social vulnerability are consequences of climate change that are not often emphasised as major climate change effects (Adger, 1999). People living in remote areas too far from schools have difficulty acquiring an education and this contributes to their condition of poverty, because people are not able to learn the necessary skills to escape their circumstances (Dessler & Parson, 2006).

Adger (2006) writes about vulnerability as being the state of susceptibility to harm from exposure to stresses associated with environmental and social change, and from the absence of capacity to adapt. In his article "Vulnerability" he discusses the impacts of climate change on people's immediate lives and how big a role it plays in creating poverty. Most land suited to agriculture is already in use, so a more efficient use of water, energy, and labour is essential to fight against the vulnerability we face (Beddington, 2010). There is a fundamental link between the challenge we face to guarantee food security throughout the 21st century and other science- and technology-related global problems, especially climate change, population growth and the need to sustainably manage the increasing demand for energy and water (Beddington, 2010). Science and technology can make a major contribution to meeting the need to feed a future population of nine billion people fairly and sustainably by providing practical solutions (Beddington, 2010). Central areas to focus on for a 'greener revolution' include:

> Crop improvement; smarter use of water and fertilisers; new pesticides and their effective management to avoid resistance problems; introduction of novel non-chemical approaches to crop protection; reduction of post-harvest losses; and more sustainable livestock and marine production (Beddington, 2010, p. 61).

Techniques and technologies from many disciplines, ranging from biotechnology and engineering to newer fields such as nanotechnology, will be needed (Beddington, 2010). Biotechnology is one of many tools of agricultural research and development (Serageldin, 1999) and it could contribute to food security by helping to promote sustainable agriculture centred on smallholder farmers in developing countries (Serageldin, 1999). The transformation will require access to and ability to apply technological advances, since future growth in food production will have to come largely from agricultural intensification on existing land (Serageldin, 1999).

2.4.10 Bad land use

Natural habitats indirectly benefiting the human race are being replaced by mass production of crops for an economic benefit instead of environmental benefits:

> Increasing agricultural yields seem an obvious way to satisfy increasing demands for food and fuel while minimising expansion of agriculture into forest areas; however, an influential literature worries that promoting agricultural innovation could enhance agriculture's profitability thereby encouraging deforestation (Villoria, Byerlee, & Stevenson, 2014, p. 1).

To add to this, research has shown that agricultural expansion (especially commercial agriculture) is the leading cause of deforestation of tropical forests (Gibbs, Ruesch, Achard, Clayton, Holmgren, Ramankutty, Foley, 2010). Trees are very important not only for the oxygen they produce, but the tree roots maintain soil structure and can limit soil erosion; they contribute to water infiltration, which reduces water run-off, encouraging the composition of a rich and productive soil. Also, tree leaves reduce the action of the wind on the soil surface. Dead tree parts that fall to the ground decompose and enrich the soil with organic matter (Puigdefâbregas, 1998).

Desertification is one of the most serious effects of bad land use and of the over-exploitation of forests. Desertification occurs when water becomes scarce or is threatened. When soil erodes or disappears because of loss of nutritive matter (due to agricultural over-exploitation), landslides occur as a result of loss of vegetation. Biodiversity declines as a result of desertification. Unfortunately, land degradation as a result of drought, saltiness or over-exploitation has direct effects on the ability of vegetation to maintain or recover itself (Puigdefâbregas, 1998). Animal species, dependent on this vegetation, have to migrate to other areas to find sufficient resources, or they risk disappearing altogether. When the vegetation cover is not given enough time to re-establish itself during rigorous grazing periods, or when grazing activities are too abundant, the land loses its ability to recover itself (United Nations Environment Programme, 2014). With science and technology we are able to trace human activity that can degrade the habitat quality for ecosystems, which ultimately impacts on the ‘free services’ that these ecosystems can provide. Scientists unravel the complex interaction between environmental and anthropogenic borders, as well as the complex systems in aquatic ecosystem. This kind of research represents a number of challenges for environmental scientists (Englerta, Zubroda, Schulza, & Bundschuh, 2015). With developments in science and technology it is possible for environmental scientists to find solutions to problems like bad land use and how to recover over-exploited lands. Rethinking city planning, rehabilitation of exploited lands and alternative forms of agriculture can make major improvements on land that has been badly used (Rao, Knight, & Samarth, 2010). Cities could be built keeping in mind the idea of a 'greener future' to influence every decision made (Hessel et al., 2014). Problems like desertification should be tackled through a multi-disciplinary approach that not only involves scientists but also stakeholders. Such an approach was adopted in the Desertification Mitigation and Remediation of Land (DESIRE) project; the aim is to select sustainable land use and management strategies based on the close collaboration of researchers with various stakeholder groups such as land users, technicians, policy makers and NGOs (Hessel et al., 2014). This project also relies on indigenous knowledge and does not accept the idea that local populations are ignorant and that they cause degradation by, for example, overgrazing. According to DESIRE, local populations generally have a high level of understanding of the local conditions. They have often lived in the area for generations and are therefore more knowledgeable about local circumstances and local land management strategies than external researchers can ever be (Hessel et al., 2014).

2.4.11 Use and abuse of technology

Technology is very important for the comfort and survival of humans. Technology such as the internet, cell phones, computers, laptops, cars, solar panels etc. makes our lives convenient and interesting. The problem with technology comes when people use its power to corrupt or disrupt. It is apparent that the use and abuse of technology in our society is becoming more common. This use and abuse of technology is present on the news, television and on the internet. The abuse of technology like hacking into business and government servers, e-mails being used to intimidate or threaten people, illegal downloading, plagiarising information from the internet, students inappropriately using cellular phones during class time, and accessing pornographic web sites are all growing concerns. High technology can be abused when computer viruses are created or wrong information is shared through social media.

Another growing fear created by technology is the fear of artificial intelligence. "Once humans develop artificial intelligence it would take off on its own, and re-design itself at an ever increasing rate. Humans, who are limited by slow biological evolution, would not be able to compete and would be superseded" (AFP, 2014, p. 1), said Stephen Hawking, who is regarded as one of the world's leading scientists. According to Hawking (2014), artificial intelligence is a major global concern. People create technology that keeps developing the ability to think like humans. Artificial intelligence would also have major implications for the loss of work for humans. When robots and computers are designed so that they can think like humans, they can basically replace humans in any form of job:

> An Artificial Intelligence could rewrite its code from scratch – it could change the underlying dynamics of optimisation. Such an optimisation process would wrap around much more strongly than either evolution accumulating adaptations, or humans accumulating knowledge. The key implication for our purposes is that an AI might make a huge jump in intelligence after reaching some threshold of criticality (Doyle, 1994, p. 19).

2.4.12 Ignorant decision makers

To understand the issues of the day, leaders need to be scientifically and technologically informed. The government needs to inform the public of issues that can be resolved with the cooperation of everyone in a country (Le Grange, 1996). This can only be done successfully if the leaders are scientifically and technologically literate to explain the complexity and impact of a problem to the community. For instance, if the government wants to start addressing the over-use of water, they need to be able to give sensible solutions to the public that can be explained through science, so the public can comprehend the part they have to play in the solution. Instead of telling people to take shorter showers, we can start showing them the amount of water that goes into the production of food, or the products they buy. This can help them to realise that changing their diet or shopping less can save more water than taking fewer or shorter showers.

Problems like deforestation, ocean depletion, energy production, over-population, Ebola, HIV and fresh water scarcity are all science- and technology-related problems. They are related to scientific knowledge and they are related to issues that society is facing. Society wants to be informed by their government and leaders about these problems related to science and technology. Global science- and technology-related problems shouldn't be left in the realms of the scientist. Governments can make scientific work a more open and democratic activity by being more open with the public and being more informed. Foreshadowing the rise in the democratisation of science, the UNESCO World Conference on Science (p. 1) stated:

> Today, whilst unprecedented advances in the sciences are foreseen, there is a need for a vigorous and informed democratic debate on the production and use of scientific knowledge. The scientific community and decision-makers should seek the strengthening of public trust and support for science through such a debate.

2.5 Science- and technology-related global problems and engineering

Engineering students have to address many topics involving scientific and technological problems in their curriculum; the impact and influence of these problems are now discussed. Civil engineers have a subject in their 3rd year dealing with environmental studies. In this subject they briefly touch on the subject of global environmental problems (Mihelcic & Zimmerman, 2010). In 2013 the civil engineering students from the University of Stellenbosch did a study on investigating the flood hydrology and river hydraulics of the Lourens River in the Strand and Somerset-West (Stellenbosch University, 2013). Here is a typical global problem, flooding, that is now being discussed on a local level. For the area around Stellenbosch, flooding seems to be a high priority since it affects thousands of people in their direct environment (like their homes, schools and hospitals). Engineering students are important to society, because they can solve problems with vital outcomes like these:

- "Deterministic and probabilistic hydrological methods were used to determine the flood recurrence intervals for both the 28 August and 15 November 2013 flood events.
- The floodplain behaviour (numerical 2D model) considering bed level changes due to erosion and sedimentation was modelled. The current flood lines were revised as an outcome of this task.
- Short-term emergency measures, as well as long-term mitigation options were analysed and priced" (Stellenbosch University, 2013, p. 1).

Knowing where engineers are needed (in terms of global problems), it is vital for educational institutions to educate students to be competent enough to handle and solve these problems. How engineers prioritise science- and technology-related global problems is of the utmost importance, because they can solve local and global problems. Knowing what engineers' priorities are, while they are in training, can assist in developing a curriculum that is responsive to their perceived needs and priorities.

Currently a priority in the Faculty of Engineering at Stellenbosch University is water and water-related subjects. In this instance the engineering students are focusing on water pollution and on the removing and treating of sewage and sewerage systems (Stellenbosch University, 2013). Solving water pollution and problems related to it aligns with the priorities of the Western Province government and what they prioritise as an important problem that needs attention (City of Cape Town, 2011). Later in this study, this information is important to indicate how the engineering curriculum influences engineering student's priorities.

Then there are some problems within the community where engineers can make a difference. Engineers are needed for their technical knowledge in helping poor communities of South Africa, for example, as engineering students are doing in Ida's Valley, Stellenbosch:

> The GMT (Geotechnical, Management & Transportation) section of the Department of Civil Engineering is at the start of a new project to assist Speelkring Pre-Primary School in Ida's Valley to upgrade and repair playground equipment. The school has a problem with vandalism by disaffected youth in the community; and the municipality has been asked to assist with the erection of a vandal-proof

> fence. Once that is in place, the staff in the section will get to work redesigning, building and reinvigorating the play equipment so that the children have a safe and stimulating play environment (Stellenbosch University, 2013, p. 1).

This is just one example of how the priorities of the students in a country can be influenced by the training, exposure and curriculum that the students receive.

In the global context engineers are related to many problems in society. Engineers are able to find many solutions for problems that they specialise in. Chemical engineers could solve the global problem that involve the production or use of chemicals, fuel, drugs, food, and many other products. Chemical engineers are responsible for solving military problems like reliable detection of dangerous disease organisms, highly toxic chemicals, and concealed explosives (Hall, 2005). Human welfare will continue to benefit from new substances, including medicines and specialized materials that chemical engineers develop and improve. Civil engineers specialise in solving problems such as: estimating sea levels, enhancing disaster management through infrastructure resilience, reducing soil erosion, improving building energy efficiency and managing groundwater (Hall, 2005). These are all global problems related to the 12 items on the RLGPI, therefore the civil engineering curriculum has to correspond with global issues like these. Electrical/electronic engineering projects aimed at solving global problems include: poverty, illiteracy and diseases-control (Hall, 2005). Mechanical engineers specialise in solving problems related to the fields of energy, bioengineering/biomedical, computers, electronics, nanotechnology and water. These also correspond with the 12 items on the RLGPI.

The question is whether and how students are being exposed to science- and technology-related global problems, and if the exposure they receive is derived from the curriculum or their own experiences/knowledge, or acquired through the media.

2.6 SCIENCE- AND TECHNOLOGY-RELATED GLOBAL PROBLEMS AND EDUCATION

It is important for education students to be aware of science- and technology-related local and global problems, especially once they are teachers. Students might have problems related to their specific environment, making their lives difficult, and the teacher should be aware of these specific problems. It is also important for teachers to make students aware of global problems that the students might not be aware of. The 17 sustainable development goals of the United Nations is an example of the kind of aims that can make students aware of global problems. Teachers can assist in helping the students to become well taught and responsible citizens, aware of global problems (Schreuder, Le Grange, & Reddy, 1998).

Natural Sciences, Social Sciences, Geography, Technology and Life Orientation are some of the subjects that some important science- and technology-related problems are discussed; students need to think about these problems and how they are related to education and the students' own lives (Stellenbosch University, 2014). Here the influence of these subjects on the students' lives depends on the student and how involved they want to be in that specific subject. On the other hand, these subjects do provide the exposure the students might need to become aware of global problems (Schreuder, Le Grange, & Reddy, 1999).

Natural sciences as a subject in the BEd (Intermediate and Senior Phase) course include science- and technology-related global problems such as water pollution, AIDS, malaria, global warming, alternative energy sources and recycling in the education curriculum. Environmental education discusses problems such as conservation, how to be a responsible citizen, water pollution, air pollution, waste removal and treatment, coal mines and the burning of fossil fuels (Waghid, 2011). Typically these specific topics are repeatedly discussed in Technology and Life Orientation (Stellenbosch University, 2014).

In the school curriculum, according to the Curriculum and Assessment Policy Statement (CAPS) of 2012 for the FET phase (Grade 10-12), the development of an understanding of science's role in society is a very important topic. This view is expressed by the DBE as follows:

> Both science and technology have made a major impact, both positive and negative, on our world. A careful selection of scientific content and the use of a variety of methods to teach and learn science should promote the understanding of science as a human activity as well as the history of science and the relationship

> between Life Sciences and other subjects. It also helps learners to understand the contribution of science to social justice and societal development as well as the need for using scientific knowledge responsibly in the interest of ourselves, society and the environment. Moreover, understanding science also helps us to understand the consequences of decisions that involve ethical issues (Department of Basic Education, 2011, p. 12).

This seems to be in line with the goals of the science and technology debate and addresses science- and technology-related problems, since the idea is focused on the link between society and science. Initial teacher educators would be expected to be aware of and critically assess global science- and technology-related problems. The question now is the extent to which teachers are trained to deliver this ideal to students and whether teachers are equipped with the right knowledge, attitudes and skills to do so. This study only explored the understanding of how teachers prioritise topics related to science and technology.

2.7 The implications of gender

Theresa McCormick (1994) describes how gender can influence and define a person and each individual's perceptions and priorities in life. McCormick said that gender identity is a crucial part of one's total self-identity. Ethnicity, race, language, age, lifestyle, physical and mental ability/disability and religion define a person. She also said that the social events that shape gender identity also shape our value system and attitudes towards others. According to McCormick (1994), attitudes and values about the self and others will have an impact on how teachers handle diversity in their classrooms and on the carrying out of non-sexist, multicultural teaching.

When looking at science- and technology-related global problems and environmental issues, measuring the difference between female and male students' rankings of these might be important. The literature reflects a remarkable difference in OECD countries and in the United States of America between boys' and girls' concerns about the environment, with girls indicating greater concern than boys about environmental issues (PISA, 2006). Optimism about solving environmental issues seems to be lower in girls than in boys. Interestingly enough, optimism also seems to be lower in more scientifically literate students. In general (according to PISA 2006), students with a greater understanding of science are also more aware of environmental issues (Bybee, 2008). This could be because they understand the impact of science and technology on the environment. These students tend to be less optimistic about the prospects of science and technology resolving the current problems in the environment. What is interesting is that boys are more optimistic than girls, but girls seem to be more concerned and feel responsible about dealing with environmental issues (Bybee, 2008).

Bybee (2008) explains that environmental issues are a global concern and human activities such as the accumulation of waste, destruction of ecosystems and the depletion of resources all have an impact on the global environment. Liveri and Kaila (2011) support this notion and recognise the inseparable relationship of all people with the environment, and how it has become obvious that it is essential to guide students to express their interest in and to take action on the environment.

The curriculum can be developed in such a way that knowledge is adapted to the students so that students can relate to this kind of thinking. Knowledge is related to attitudes and more knowledge leads to more environmentally responsible behaviour (Liveri & Kaila, 2011). This is in line with Bybee's (2008) view when he describes how attitudes are linked to knowledge. He suggests that educating students is the best way to make a change, because students' knowledge of science- and technology-related problems might encourage them to make a change in the world and become more environmentally responsible. When students are educated, it might start to influence their behaviour:

> Environmental education is necessary for acquiring knowledge and for the fostering of positive attitudes to the natural environment. To obtain environmental creative thinking and responsible environmental behaviour positive attitudes towards the environment needs to be fostered (Liveri & Kaila, 2011, p. 1075).

When we investigate the differences in gender concerning student success in science, it is evident that women are far from enjoying the same opportunities in science education as men. A myriad studies, for example, document the numbers and experiences of female and ethnic minority students in science (Ginorio, 1995). Ginorio (1995), writing about female experiences in science education, says that it is difficult to deny that the climate – or culture – of science has been unfriendly to women, ethnic minorities and people with disabilities.

2.8 Chapter summary

This chapter has presented the literature study and contains an introduction, an outline of previous research findings on prioritising STS global problems, the use of rank-order scales in educational research, the theoretical basis for selection of the 12 RLGPI items, science- and technology-related global problems and engineering; science and technology-related global problems and education; and the implications of gender. The research methodology that informed this study is also discussed.

CHAPTER 3
RESEARCH METHOD

3.1 Introduction

This chapter discusses the research methodology, specifically: survey design, the setting of the survey, the samples, the reliability of the RLGPI, the hypotheses, the selection of dependent and independent variables, data collection, data analysis, the selection of statistical methods and ethical clearance, followed finally by a chapter summary. The chapter also discusses the strengths and weaknesses of the research methodology.

3.2 The Quantitative Methodological Paradigm of the research

This is a quantitative research study because it concerns controlled settings and selected samples from which quantitative descriptions are drawn and certain explanations are offered and predictions made. Quantitative methods emphasise objective measurements and the statistical, mathematical or numerical analysis of data collected through polls, questionnaires and surveys, or by manipulating pre-existing statistical data using computational techniques (Cohen, Manion, & Morrison, 2011). The researcher uses tools such as questionnaires or computer software to collect data. Quantitative research focuses on gathering numerical data and generalising the findings across groups of people or using the data to explain a particular phenomenon (Babbie, 2010). The aim of doing quantitative research is to discover the relationship between one thing (an independent variable) and another (a dependent or outcome variable) within a certain group (Babbie, 2010). Quantitative research designs are categorised into two broad types: descriptive (single test done on subjects), where only associations between variables are established; or experimental (subjects tested before and after a treatment), where causality is determined (Cohen, Manion, & Morrison, 2011). Quantitative research focuses on convergent reasoning rather than divergent reasoning, for example, to generate a variety of ideas about a research problem in a spontaneous, unrestrained style. The data are usually gathered using structured research instruments and the results are based on larger sample sizes that are representative of the population (Babbie, 2010). The research study can usually be copied or duplicated, because of its high reliability, and there is usually a straightforward research question to which impartial answers are sought (Cohen, Manion, & Morrison, 2011).

The research strategy is hypothetical-deductive and tends towards the generalisation of the findings. The focus is usually narrow and typically involves testing specific hypotheses (Fleiss, Levin & Paik, 2013). In this study a quantitative survey was conducted, but it also incorporated three qualitative questions, which were analysed by doing a content analysis of each of the responses to the qualitative questions. Given that this qualitative component forms only a small part of the study, the study as a whole does not meet the criteria to be classified as a mixed-methods study.

3.3 Data-Collection Strategies

The data-collection strategy consisted of survey sampling.

3.3.1 Survey Design

The research method used in this study was survey sampling. A survey is defined as the collection of data for the purpose of scholarly inquiry through the use of a standardised questionnaire administered by specially trained researchers (in person or over the phone) or distributed to a (randomly) selected sample of respondents for self-completion (Fleiss, Levin & Paik, 2013). Kuechler (1998) avers that the survey method is the single most important approach in empirical social research. He explains that the survey method simply provides a mirror to the public and helps to foster a comprehensive dialogue in an open society. At face value, the survey method is genuinely democratic; everyone has the same chance to be heard and everyone's opinion counts exactly the same (Cohen, Manion, & Morrison, 2011). Therefore, the survey method can provide the general public with an image of itself. In the context of educational research, surveys are used to provide a comprehensive, representative summary of specific characteristics, beliefs, attitudes, opinions or behaviour patterns of a group of students or teachers.

In order to inform the research design, literature on the use of survey techniques was consulted (Fleiss, Levin, & Paik 2013). There are two basic survey designs: cross-sectional surveys and longitudinal surveys. Both are observational, but cross-sectional surveys are used in studies where comparisons are made at a single point in time, whereas longitudinal surveys are used in studies where comparisons are made over a certain period of time (Fleiss, Levin, & Paik, 2013). A cross-sectional survey design was used in this study, because the potential for gaining significant insights is greatly increased by the availability of comparative data.

The survey samples were convenient respondents doing specific study majors (BEd and BIng), which facilitated the data gathering and therefore the research process as a whole. Even though this kind of survey and method of sampling has its limitations, such as not being able to collect any in-depth data of an instance in action, it is still satisfactory for the purposes of a Master's thesis and to produce data indicating broad trends that might inform further research (Cohen, Manion, & Morrison, 2011).

In this study the survey was administered directly to students during lecture periods. The surveys were administered directly to the students by the researcher and the students had 10 to 15 minutes to complete the survey. This ensured that there was a high response rate. The students completed the questions and then the researcher collected the surveys from the participants. In general, the more survey questionnaires are completed, the more accurate the data and this in turn enhances the generalisation of the results, allowing for greater objectivity and accuracy of results.

Quantitative surveys help to recognise and isolate specific variables when attempting to determine correlations and relationships between variables. Generally, quantitative survey methods are designed to provide summaries of data that support generalisations about the phenomenon being studied (Cohen, Manion, & Morrison, 2011). Usually the survey can be used in many cases and it employs prescribed procedures to ensure validity and reliability (Babbie, 2010). Applying well-established standards means that the survey findings can be used again, and then analysed and compared with similar findings from other studies conducted with the survey method (Cohen, Manion, & Morrison, 2011). With the data acquired from a survey a large number of sources of information can be summarised and comparisons can be made across studies done with the same survey (Babbie, 2010). Surveys help the researcher to reduce personal bias and keep the researcher at a 'distance' from the participating subjects (Babbie, 2010).

3.4 Development of the survey instrument

3.4.1 Revisions of the LGPI

The original LGPI instrument required people to rank 15 items. In this study the LGPI was revised and renamed as the RLGPI, then the RLGPI took on a new form: picking the best and worst items; therefore the nature of the instrument changed. The original scale was updated because some items or sub-categories of the items might have become outdated. The 15 items were reduced to 12 items. The items that were removed included: *The provision of mass housing for human beings, Mineral resources* and *Nuclear power stations*. The new item added was *Artificial intelligence*. Other items were re-named, such as *Extinction of plants and animals* became *Loss of biodiversity, Decision makers* became *Ignorant decision makers, Unsafe substances* became *Hazardous substances, Energy shortages* became *Energy needs* and *World hunger* and *food supplies* became *World hunger and food resources.* Some items were combined to make one item, for instance, *Mineral resources* and *Extinction of species* became *Loss of biodiversity.*

Unsafe substances as in the LGPI (renamed *Hazardous substances* in the RLGPI) includes the following items: *waste dumps, poisonous chemicals, lead paints, electromagnetic wave radiation from the sun* and *microwave oven radiation*. The item added to the RLGPI is *toxic chemicals*. The items not added to the RLGPI are *poisonous chemicals, microwave oven radiation* and *lead paints.*

Human health and disease includes these items on the LGPI: *catching and non-catching disease such as AIDS, exercise, mental health, stress, noise, diet* and *nutrition*. The items that were added to the RLGPI were *malaria* and *tuberculosis*.

The LGPI has these items under *Fresh water supplies*: *waste disposal, river mouths, water supply and distribution, ground water contamination, fertiliser contamination, waste water treatment and prediction* and *control of floods and droughts*. The items added to the RLGPI are *unsafe and unsanitary water sources* and *water-intensive human activities in agriculture and factories*. The items not added to the RLGPI are *river mouths, water supply and distribution* and *waste water treatment*.

The LGPI has these items under *Population growth*: *increase in world population, immigration, living space* and *town planning*. The items added to the RLGPI are *over-population* and *carrying capacity*. The items not added in the RLGPI are *increase in world population* and *town planning*.

Extinction of plants and animals in the LGPI (renamed *Loss of biodiversity* in the RLGPI) includes the items: *fewer types of animals remaining, over-fishing, pollution and reduction of life in the oceans* and *wildlife protection*. Added items to the RLGPI are *endangered and extinct animals and plants, desertification* and *deforestation*. The items that were not added to the RLGPI were: *fewer types of animals remaining* and *over-fishing.*

In the LGPI *Energy shortages* (renamed *Energy needs* in the RLGPI) includes the items: *human manufactured fuels, solar power, fossil fuels, fewer resources, conservation* and *oil production.* Items added the RLGPI are: *fossil fuels* and *wind power*. The items removed were *human manufactured fuels* and *conservation*.

War technology in the LGPI includes: *nerve gas, nuclear developments* and *nuclear weapons threat*. The items added to the RLGPI are *terrorism* and *biological warfare*. The items removed were *nerve gas* and *nuclear developments*.

In the LGPI *Air pollution* includes the items: *acid rain, CO2, depletion of ozone layer, smoky smog* and *global warming.* The items added to the RLGPI were *methane gas from livestock* and *transportation*. The item removed was *smoky smog*.

World hunger and food supplies (renamed *World hunger and food resources*) include *food production, crops* and *agricultural methods* in the LGPI. Items added to the RLGPI are *food security, pesticides* and *herbicides*.

Bad land use as in the LGPI includes *soil erosion, reclaiming of land, city spread and growth, wildlife habitat loss, removal of forests, spreading of deserts* and *increase in the salt content of soils.* Items added to the RLGPI were *palm oil plantations*; the items removed were *reclaiming of land* and *increase in the salt content of soils*.

Use and abuse of technology in the LGPI includes the items: *the electronic information explosion, education and the distribution of knowledge, genetic engineering, worldwide communication networks, job creation, indoctrination by television,* and *the rapid sharing of controversial information by satellite*. The item added to the RLGPI is *uncontrollable artificial intelligence leading to world domination*. The items removed include the *electronic information explosion, worldwide communication networks, job creation* and *the rapid sharing of controversial information by satellite*.

Ignorant decision makers in the LGPI includes the items: *scientifically and technologically illiterate community leaders* and *science and the humanities as two different cultures.* The item added to the RLGPI is *corrupt government*.

3.4.2 Reliability of LGPI

The original instrument's reliability was established in 1995, when a study was conducted with a sample of 58 Cape Town secondary school students in order to determine the test/retest reliability of the LGPI. The instrument yielded a reliability coefficient of r = 0.90, when the intact sample was retested after an interval of one day (Le Grange, Rochford, & Sass, 1996). The reliability of the RLGPI will be discussed later in this chapter.

3.4.3 Validity of the LGPI

The validity of the items on the LGPI was established in 1994 when Ndodana et al. reported that 20 engineering lecturers identified several important issues that needed to be included in any updated version of the 1984 Bybee scale. Experts in the fields related to science and engineering were consulted to assist in the selection of the items. The wording of the instrument was simplified and the items were updated and refined by a panel of 12 Science and English teachers (Le Grange, Rochford, & Sass, 1996). The LGPI therefore went through several iterations of validation.

3.5 The Best-worst-scale

The original LGPI scale was a full ranking survey instrument, whereas the RLPGI that was administered to the two groups of undergraduate students was a best-worst scale. The next section discusses the motivation behind using this scale and its reliability and validity in detail.

3.5.1 The Best-Worst Scale Ranking Method

In a best-worst scale each respondent may be asked to pick the most valued item and the least valued item on the list. Other names for this technique include most/least and max difference analysis. Respondents are asked to pick the most important item and the most/least preferable ones. Even the method of picking one or more items requires the simultaneous contrast of the whole set of entities, but the procedure is much less demanding for respondents than full ranking scales because just a few items are pre-selected for top or bottom positions after a first reading of the list (see Appendix).

In this study scores for each item were calculated by assigning a -1 if the item was selected as least important, +1 if the item was selected as most important, and 0 if the item was not selected. These scores were then summed across items per respondent to get an importance score for each item across all the respondents.

The relationship between the items' choices and the underlying values is: $Px(1) \geq x(i)= P\xi(1) \geq \xi(i)$ (i -=(1),..., p), where x(1) denotes the item selected as best. An analogous formula applies for x(p), the worst item (Fleiss, Levin & Paik, 2013). This procedure generates data that are "weakly ordered", since a complete ordering cannot be determined for the items. Nevertheless, a preference matrix P can be estimated if a sufficiently large number of individuals are surveyed on a common choice set, if the ξ is non-compensatory. The pick-the-best strategy is preferable in spite of its simplicity. In all bounded-rationality contexts and, in particular, in social and psychological studies this strategy showed particular plausibility (Martignon & Hoffrage, 2002).

This procedure is the least burdensome among those that require respondents to evaluate a whole set of alternatives at a time, because just the extremes are to be chosen (Martignon & Hoffrage, 2002). It may be considered a truncated form of the complex tasks required by the ranking technique. It can be applied easily with any interviewer-based or self-administered questionnaire, but it can only be applied in an interviewer-based survey if the list to be recalled is short.

3.5.2 Advantages of best-worst scaling (BWS)

1. It is a difficult task to sort 12 items at once in order of importance, as in a rank-order scale. The respondents of BWS in this study had to choose from just 4 items for each block and select the lowest and highest in terms of importance.

2. In previous studies, after all 12 items had been sorted, it was indicated that the items higher on the list had a better chance of being designated as important (Lee, Soutar & Louviere, 2008). With BWS each item occurs once with all the other items. In this study there were 12 items which are less than usual for BWS; consequently there are a few times where two items might occur together, because there is not a balanced design for 12 items. However, this does not cause a problem when analysing the data (Lee, Soutar, & Louviere 2008).

3. The statistical analyses allocate an item a score of -1 if it was marked as least, 0 if it was not marked, and +1 if it was marked as most. Because each item appears four times in the design, the scores can range from -4 to +4, where -4 is the least important and +4 the most important. This is a relatively easy way to analyse the data compared to the typical rank-order scaling.

3.5.3 Possible sampling errors

Sampling and response errors are independent of each other and can be evaluated separately. The sampling error depends on the sampling design and its evaluation (Kumar, 2014). The response error is composed of systematic ("bias") and random components. The systematic component is common to all respondents, is constant regardless of the number of responses obtained, and is at risk of being confused with the latent value ξi (Kumar, 2014). The random errors vary within and between individuals. Response errors vary according to the following factors. The respondent's answering style, e.g. his or her capacity and willingness to respond correctly, may have an impact (Kumar, 2014). The individual error may be either random (zero mean in repeated surveys) or systematic (constant over repeated surveys). Group response biases may occur, i.e. common to a population segment or common to the whole assignment of an interview error supervisor. They are measurable as within-group correlated response errors. The survey context, i.e. the set of social and physical characteristics of the interview setting, non-neutral setting may generate systematic errors. In this study possible errors are that students could have been tired when completing the survey as they had completed a classroom activity before the completed the survey. Students sitting next to each other who were not willing to complete the survey could have taken answers from other respondents and not given their own. Some students might have been unwilling to complete the survey and only completed it half way through and handed in uncompleted surveys. This was avoided by making the survey relatively short and having the students complete the surveys in a controlled environment or a lecture hall.

3.6 The setting of the survey

This survey was conducted at Stellenbosch University. Stellenbosch University is a public research facility situated in the town of Stellenbosch. Africa's first microsatellite, Stellenbosch University Satellite (SUNSAT), launched in 1999, was invented and manufactured at Stellenbosch University (Richmond, 2002). The university originated as Stellenbosch Gymnasium in 1864 and opened in 1866 (Pretorius, 2014). Less than a decade after the establishment of the Gymnasium, in 1874, the so-called Arts Department was founded (Pretorius, 2014). It was then renamed Victoria College to celebrate the 50-year jubilee of Queen Victoria (Pretorius, 2014). Jannie Marais, a wealthy Stellenbosch farmer, donated £100 000 to the funds required to allow the status of Stellenbosch College to become a university before his death in 1915 (Pretorius, 2014). By 1917 Victoria College had 503 students and 40 lecturing staff (Stellenbosch University, 2013). The adoption of the University Act in 1918 by the then

Union of South Africa Parliament laid the first stone for the establishment of a university (Pretorius, 2014). Since 1918 the number of students and staff at Stellenbosch University has expanded significantly. By the start of 2013 the institution has reached a student force of 31 000 students, a lecturing staff of 939, and around 50 research and service divisions (Stellenbosch University, 2013).

Stellenbosch University is a historically white and Afrikaans University, but since 1994 its monocultural identity has been challenged. Today Stellenbosch University is a relatively diverse higher education institution in Africa (Cloete, 2016). It has a diverse racial profile and people from various backgrounds with different income and demographics study at Stellenbosch University. One of the current issues at Stellenbosch University is the need for sustainable funding and fees for all students (Cloete, 2016). In South Africa there is a need for the undergraduate system to be restructured (Cloete, 2016).

The aim of the Faculty of Education at Stellenbosch University is to produce teachers and trainers who can meet the differentiated educational needs of the wider community. The Faculty of Education also aims to make a contribution towards developing the human potential in the southern African community. The BEd (Foundation Phase Education) and the BEd (Intermediate Phase Education) are the two undergraduate programmes that the Faculty offers (Stellenbosch University, 2011). These two programmes both take four years to complete and only the first year of the two programmes is the same; after their first year students diverge into the programme of their choice: Foundation Phase or Intermediate/Senior Phase (Stellenbosch University, 2011).

The Engineering Faculty at Stellenbosch University offers the platform for students who are primarily concerned with the progress of technology through innovation, creativity and change to become professional engineers (Stellenbosch University, 2011). Bachelor of Engineering programmes (BIng) at Stellenbosch University are four-year courses (Stellenbosch University, 2011). In the first year all students take the same compulsory subjects; after that students' programmes diverge from each other, depending on the specific programme they chose (Stellenbosch University, 2011). The following are the BIng programmes offered by Stellenbosch University: Civil Engineering, Mechanical

Engineering, Chemical Engineering, Electric/Electronic Engineering, Mechatronic engineering. In the first two years a foundation of mathematics and the natural sciences and engineering sciences is offered, and in the third and fourth years, students learn how to apply their knowledge to solve technical problems (Stellenbosch University, 2011).

3.7 Samples used in this study

The two main samples consist of students at Stellenbosch University. These are education students and engineering students. All samples were tested during the period March-April 2016.

Sample 1 (n=56) comprised final-year civil engineering students at Stellenbosch University.

Sample 2 (n=58) consisted of final-year education students at Stellenbosch University.

3.8 The Reliability and Validity of the RLGPI

3.8.1 The validity of the RLGPI

As previously discussed, the original LGPI had 15 items. After doing research on the latest global problems according to the latest literature, the 15 items were updated to a revised set of 15 items. These items were: *Population growth, Water shortage, Pollution of water, Air, soil and light, Poverty, Climate change, Natural resources depletion, Waste disposal, Loss of biodiversity, Bad land use, Ocean depletion, Public health issues, Agriculture, Energy shortages* and *Artificial intelligence*. This 15-item instrument was given to four people knowledgeable about these 15 topics. One was given to the Environmental Education professor at the Faculty of Education. Another was given to a professor involved with the civil engineering subjects, specifically Environmental Studies. Another survey was given to an expert in environmental studies at the Natural Sciences Faculty. A survey was also given to a research assistant in the Department of Microbiology for critical inputs. These experts examined the instrument and ranked the items according to their priorities, based on their expert knowledge. The items that were ranked the lowest were removed from the list and the remaining 12 items were used in the final version of the survey. After considering the experts feedback on the survey, the original scale that was used in previous research by Bybee and Mau (1986), Bybee and Najafi (1986), Ndodana, Rochford and Fraser (1994), Le Grange, Rochford and Sass (1995) and Le Grange (1996) was consulted again. The descriptions of each item with respect to the most important recognised major global problems related to science and technology were then added. The names used on the original LGPI were re-used and adapted according to the latest literature reviewed. The scale was also changed from a rank-order scale to a best-worst-scale, for the reasons discussed above in section 3.5.2.

3.8.2 Reliability of the RLGPI

Theory

Reliability is the degree to which an assessment tool produces stable and consistent results. In other words, according to Drost (2011), reliability is the extent to which measurements are repeatable – even when the measurements are taken by different researchers, on different instances, under different circumstances, with adapted instruments which measure the same thing. Drost (2011) notes that reliability is consistency of measurement, or stability of measurement over a range of conditions in which similar results should be obtained. One way of determining the consistency of a test is to determine the reliability coefficient (r) (Le Grange, 1996). The reliability coefficient (r) is acquired from the correlation coefficient: +1 being the perfect correlation, 0 being not any correlation and -1 the most legitimate inverse correlation (Le Grange, 1996).

Procedures and properties of the instrument

The method used to determine the reliability of the RLGPI was the test-retest method. Test-retest reliability is a measure of reliability obtained by administering the same test twice over a period of time to the same group of individuals (Drost, 2011). The scores from Test 1 and Test 2 can then be correlated in order to evaluate the test for stability over time. The method used to determine the rank correlation coefficient of the ranks of the mean scores gained in Test 1 and Test 2 is the Spearman rank correlation coefficient. Spearman's correlation coefficient, (*P*, also signified by r_s) measures the strength of association between two ranked variables. Variables that are ordinal or an interval are a requirement for using the Spearman's correlation coefficient. The Spearman correlation coefficient, *P*, can take values from +1 to -1. A *P* of +1 indicates a perfect association of ranks, a *P* of zero indicates no association between ranks and a *P* of -1 indicates a perfect negative association of ranks. The closer *P* is to zero, the weaker the association between the ranks.

The method for the computing of Spearman rank correlation coefficients for the test/retest was used as in the research done by Le Grange (1996) as follows: a list of the 12 items on the RLGPI was made by doing research on the latest science- and technology-related problems and consulting experts in that field; next to each item entry the mean rank score of the first variable (test) and the mean rank score of the second variable (retest) were entered; the rank 1 was then assigned to the smallest test mean rank score and the rank of 12 to the largest mean rank score of the test; the same was done for the retest; the difference (d) between the test mean rank scores and the retest mean rank scores for each item was then computed; finally the values n = 12 were entered into the equation, Σd^2, and Spearman Rho (P) calculated.

When using a rank-order scale such as the RLGPI, the test-retest method is the best technique for determining reliability. When working with scores that are in the form of rank scores, a non-parametric statistical method works best when trying to determine the reliability coefficient. Therefore the Spearman rank correlation was used as the method of choice. When a complete pilot group of 26 engineering students from Stellenbosch University was retested with the RLGPI over an interval of one week in July 2016, a reliability coefficient of $r = 0.82$ was obtained.

3.9 Hypotheses

There were five null hypotheses tested in this study.

3.9.1 Null Hypothesis 1 (Fourth-year engineering students compared to fourth-year education students)

a) There will be no statistically significant difference between the mean ranking score of engineering students and education students on each of the individual items on the revised Le Grange Priorities Instrument (RLGPI).

3.9.2 Null Hypothesis 2 (Female fourth-year engineering students compared to male fourth-year engineering students)

a) There will be no statistically significant difference between the mean ranking score of female engineering students and male engineering students on each of the individual items on the revised Le Grange Priorities Instrument (RLGPI).

3.9.3 Null Hypothesis 3 (Female fourth-year education students compared to male fourth-year education students)

a) There will be no statistically significant difference between the mean ranking score of female education and male education students on each of the individual items on the revised Le Grange Priorities Instrument (RLGPI).

3.9.4 Null Hypothesis 4 (Female fourth-year engineering students compared to female fourth-year education students)

a) There will be no statistically significant difference between the mean ranking score of female engineering students and female education students on each of the individual items on the revised Le Grange Priorities Instrument (RLGPI).

3.9.5 Null Hypothesis 5 (Male fourth-year engineering students compared to male fourth-year education students)

a) There will be no statistically significant difference between the mean rankings score of male engineering students and male education students on each of the individual items on the revised Le Grange Priorities Instrument (RLGPI).

3.10 Selection of dependent and independent variables

The dependent variables in this study are the BWS of the education students and engineering students.

The independent variables are the 12 items (global problems) on the RLGPI.

Education and engineering students' samples will be compared in terms of their responses to the 12 global problems on the RLGPI. A sample of the different genders is also compared in relation to their responses to the 12 global problems on the RLGPI.

3.11 Data collection

Pilot Study

After permission was obtained, the surveys were administered by the researcher to 20 education students in the first 15 minutes of the beginning of the class period. After 15 minutes, when all the students had completed the surveys, the surveys were collected by the researcher. Access to the engineering students was granted by getting permission from the specific lecturers teaching the civil engineering students. First the researcher contacted the professor (through e-mail) who teaches second-year engineering students asking for permission to conduct the pilot study. After permission was granted, the survey instrument was administered by the researcher to 20 engineering students within the first 10 minutes of the beginning of a tutorial class period. After 10 minutes, when all the students had completed the surveys, the surveys were collected by the researcher. The pilot study was done to determine how long students would take to complete the questionnaires, to see whether students understood the instructions and to find out whether the content of each item was understood.

Main Study

For the purposes of this research, a direct data-gathering technique was used. The researcher had direct contact with the survey respondents. The researcher gathered information by asking the survey respondents questions directly through a survey questionnaire. Stellenbosch University granted permission for the researcher to contact lecturers, who facilitated access to students. As mentioned, the researcher first contacted the professor (through e-mail) who teaches second-year education students for permission for the pilot study to be conducted.

After this a fourth-year lecturer of the education students was contacted (through e-mail) so as to gain access to a larger group of students for the main study. The researcher explained the method of completing the survey to the students before the survey was administered. After 15 minutes the researcher collected the surveys. The data were collected during the period May to August 2016, using 15-minute slots as part of normal class-time of formal instruction. Ninety-five percent (95%) of the questionnaires were complete and usable. Similarly, a lecturer of the fourth-year engineering students was contacted (by means of e-mail) in order to facilitate access to a larger group of civil engineering students for the main study. It was arranged with the lecturer for the survey instrument to be administered to students. The researcher explained the method of completing the survey to the students before the survey was administered, and gave them guidance on how to complete the survey. After 10 minutes the researcher collected the surveys.

Participants were not allowed to use external influences such as the internet or social media to inform their decisions when they were ranking the 12 items. This was monitored by lecturers and the researcher. Therefore data collected in this study are reliable measurements of participants' personal priorities and knowledge.

3.12 DATA ANALYSIS

3.12.1 Quantitative data analysis

As mentioned, the RLGPI was administered to fourth-year engineering and education students. Mean ranking scores were compared between attributes and groups using mixed model repeated measures ANOVA. For post-hoc testing Fisher's least significant difference (LSD) was used. Analyses were conducted using Statistica 13. The initial F-test of the ANOVA tested the hypothesis that the mean rankings are equal across all attributes. If this test is rejected, then specific pairwise comparisons are made between two attributes at a time to determine in more detail the differences between attributes. These pairwise comparisons are the so-called post-hoc tests. This was done for the purpose of disclosing significant similarities and differences between the responses to the RLGPI items.

3.12.2 Qualitative data analysis

The qualitative data analysis was done by administering the RLGPI surveys to fourth-year engineering and education students. Three qualitative questions were added to the last section of the survey instrument.

Themes identified from the qualitative data, for example, 'Personal- and introspective-problems' and 'Concerns about and for the Earth'. Themes like these were identified by gathering all the qualitative data and identifying themes that were recurring. These were the themes that were discussed most often by the respondents. From these questions more accurate assumptions could be made by the researcher about participants' reasons for ranking their priorities as they did.

3.13 ETHICAL CLEARANCE

It was necessary to apply for ethical clearance from Stellenbosch University. The ethics application process starts within the respective departments via the Departmental Ethics Screening Committee (DESC). Applications are screened to determine their risk levels. Applications of minimal and low risk are screened by the DESC and are ratified by the Research Ethics Committee (REC). Only applications with medium to high ethics risks are referred to the REC for full review. All research involving human participants must comply with the following principles: relevant to the needs and interests of the community in which the research is conducted; have a valid scientific methodology; ensure research participants are well informed about the purpose of the research and how the research results will be disseminated and that they have consented to participate; where applicable, ensure research participants' rights to privacy and confidentiality are protected; ensure the fair selection of research participants; process must be preceded by a thorough risk-benefit analysis and thorough care must be taken to ensure that research in communities is effectively coordinated and does not place an unwarranted burden on such communities (Horn, Graham, Prozesky, & Theron, 2015).

A final version of the proposal was submitted for DESC/REC approval. The primary purpose of the DESC checklist and process is to ensure that all researchers adequately consider the ethical implications of their own research. There is a checklist that needs to be completed before the online application process can begin.

After approval for ethical clearance was granted, the process of applying for institutional approval began. See the ethical clearance letter in the Appendix, page 139-140. Stellenbosch University students were included in the research as participants and were used as the data source; therefore the researcher had to apply for institutional permission from the Senior Director: Institutional Research and Planning. This request had to include the research proposal, informed consent form(s) and questionnaires/data-collection tools. The Senior Director of Institutional Research and Planning accepts the application for institutional permission once he or she has obtained the DESC (low-risk research) or REC (medium-/high-risk research) ethical clearance. Permission was required from external institutions and organisations and it was therefore necessary to ensure that the permission was *informed* institutional permission. In other words, before a student completed the survey he/she was informed about the purpose of the study, knew how the results will be disseminated and was clear on whether his/her identity would be revealed or not.

When the surveys were administered to the students, the informed institutional permission was explained to them beforehand. Students who were unwilling to complete the surveys after the informed institutional permission was explained to them were excused and they didn't have to complete the survey.

3.14 Chapter Summary

The research method, the setting of the survey, a description of the samples, the reliability of the measurement instrument, hypotheses to be tested, selection of dependent and independent variables, data collection, data capture, the selection of appropriate statistical methods have been described in this chapter; the process of ethical clearance is also discussed in the last section. The results and findings of the research study follow in Chapter 4.

CHAPTER FOUR
RESULTS AND FINDINGS

4.1 Introduction

This chapter presents the findings of the analysis and the interpretation of both the quantitative and qualitative data. The results are represented in summarised form by discussing the analysis of each of the hypotheses independently. An amplified explanation and discussion of the emerging significant differences between the samples are provided in Chapter 5.

4.2 Presentation of quantitative data

The presentation of the quantitative data is based on the analysis of the responses of the respondents to whom the RLGPI that was administered.

4.2.1 Analysis of Questionnaires

Of a total of 120 questionnaires distributed, 114 were completed and were used for computing the results. A total of 58 questionnaires were completed by education students and a total of 56 questionnaires were completed by engineering students.

This first section of the questionnaire sought to identify the items that were most popular to be ranked in the top three positions, and to establish what the major differences between female and male students were as well as the differences between education and engineering students. Gender differences within the same sample were also analysed. The responses to the questionnaires are summarised in the next chapter there is a maximum of 58 respondents and the other of 56 respondents.

The results presented in terms of the five hypotheses that were to be tested follow below.

Ranking	**Male**	**Female**
1st place	Fresh water supplies	World hunger and food resources

2nd place	World hunger and food resources	Fresh water supplies
3rd place	Human health and disease	Human health and disease
4th place	Population growth	Loss of biodiversity
5th place	Energy needs	Population growth
6th place	Ignorant decision makers	Energy needs
7th place	Air pollution	Air pollution
8th place	Loss of biodiversity	Ignorant decision makers
9th place	Hazardous substances	Hazardous substances
10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	Use and abuse of technology
12th place	War technology	War technology

Table 4.1: The way engineering and education students ranked the 12 science-and technology-related global problems listed on the RLGPI.

4.3 HYPOTHESIS TESTING

This chapter presents and analyses the results of the survey. The results are summarised by presenting Hypotheses 1 to 5 in order, including the p-value where statistically significant differences are evident. The p-value, or calculated probability, is the probability of finding the observed, or more extreme, results when the **null hypothesis (H_0)** of a study question is true – the definition of 'extreme' depends on how the hypothesis is being tested. P is also described in terms of rejecting H_0 when it is actually true; however, it is not a direct probability of this state.

4.3.1) Null Hypothesis 1 (Fourth-year engineering students compared to fourth-year education students)

Ranking	Engineering	Education
1st place	Fresh water supplies	World hunger and food resources
2nd place	World hunger and food resources	Fresh water supplies
3rd place	Human health and disease	Human health and disease
4th place	Energy needs	Loss of biodiversity
5th place	Population growth	Population growth
6th place	Ignorant decision makers	Energy needs

7th place	Air pollution	Air pollution
8th place	Loss of biodiversity	Ignorant decision makers
9th place	Hazardous substances	Hazardous substances
10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	Use and abuse of technology
12th place	War technology	War technology

Table 4.2: The way that engineering and education students ranked the 12 science-and technology-related global problems listed on the RLGPI.

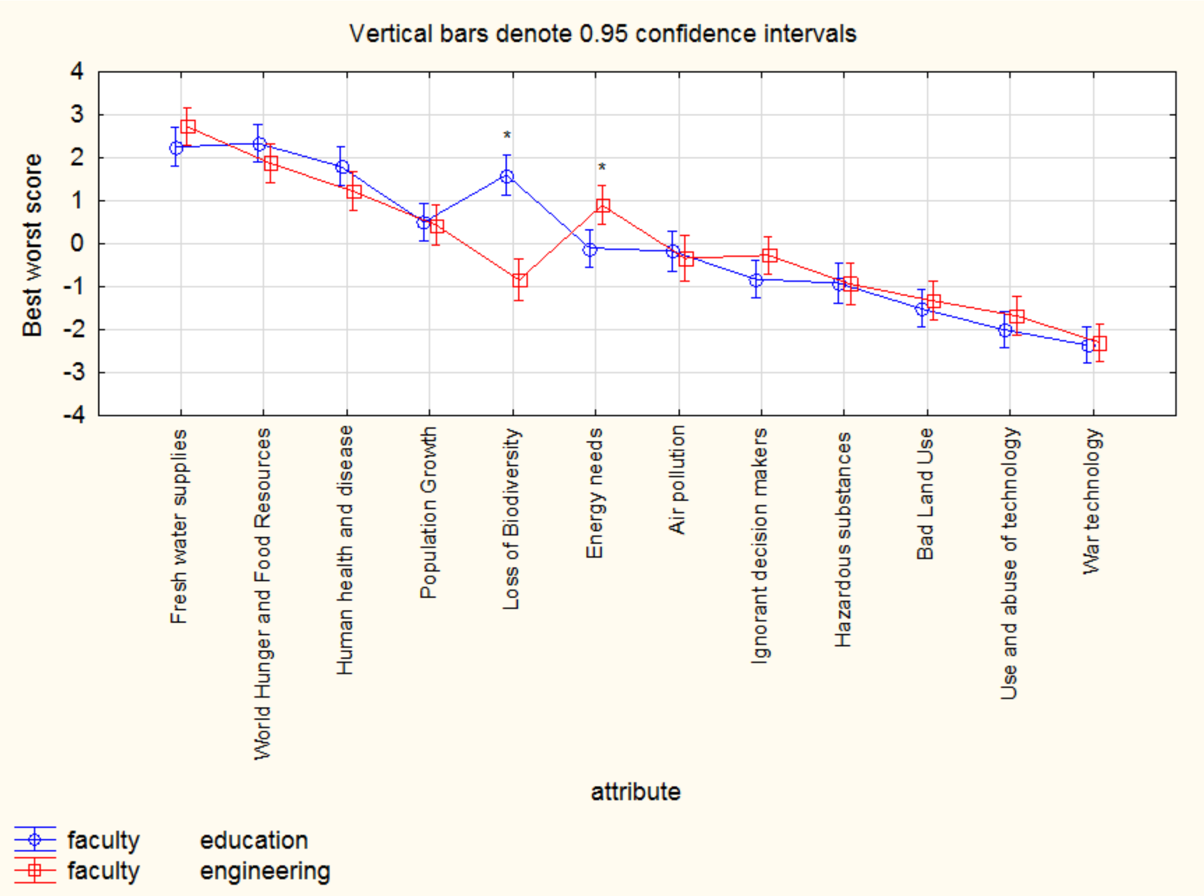

Figure 4.1: Line graph indicating the best-worst rankings of the fourth-year education students compared to the fourth-year engineering students when the different scores achieved by the different faculties were compared at Stellenbosch University in 2016.

Hypothesis 1 – that there are no significant differences between the mean ranking scores of education students and engineering students on the RLGPI (individual items) – was not supported. There were significant differences between engineering students and education students with respect to their mean scores on 2 of the 12 major science- and technology-related global problems, taken individually. There was a statistically significant difference between the education and engineering students ranking of *Loss of biodiversity* and *Energy needs* ($p<0.01$). Differences in rankings are statistically significant when the p value is equal to or smaller than 0.05 ($p < 0.05$). *Loss of biodiversity* is a global problem often discussed in the education module at the university. This could suggest that the education programmes offered in the Faculty of Education might have some influence on students' priorities when ranking the 12 items on the RLGPI. *Energy needs* was an item ranked much higher by engineering students than by education students, who it ranked at 4th place and 6th place, respectively. *Energy needs* is a global problem often captured in curricula in the Faculty of Engineering. This could also indicate that the discipline of civil engineering might have some influence on students' priorities when ranking the 12 items on the RLGPI. This will be discussed more fully in the next chapter.

4.3.2) Null Hypothesis 2 (Female fourth-year engineering students compared to male fourth-year engineering students)

Ranking	Engineering Male	Engineering Female
1st place	Fresh water supplies	Fresh water supplies
2nd place	World hunger and food resources	World hunger and food resources
3rd place	Human health and disease	Energy needs
4th place	Energy needs	Human health and disease
5th place	Population growth	Population growth
6th place	Air pollution	Ignorant decision makers
7th place	Ignorant decision makers	Hazardous substances
8th place	Loss of biodiversity	Loss of biodiversity
9th place	Hazardous substances	Air pollution
10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	War technology
12th place	War technology	Use and abuse of technology

Table 4.3: The way that fourth-year engineering male and engineering female students ranked the 12 science- and technology-related global problems listed on the RLGPI.

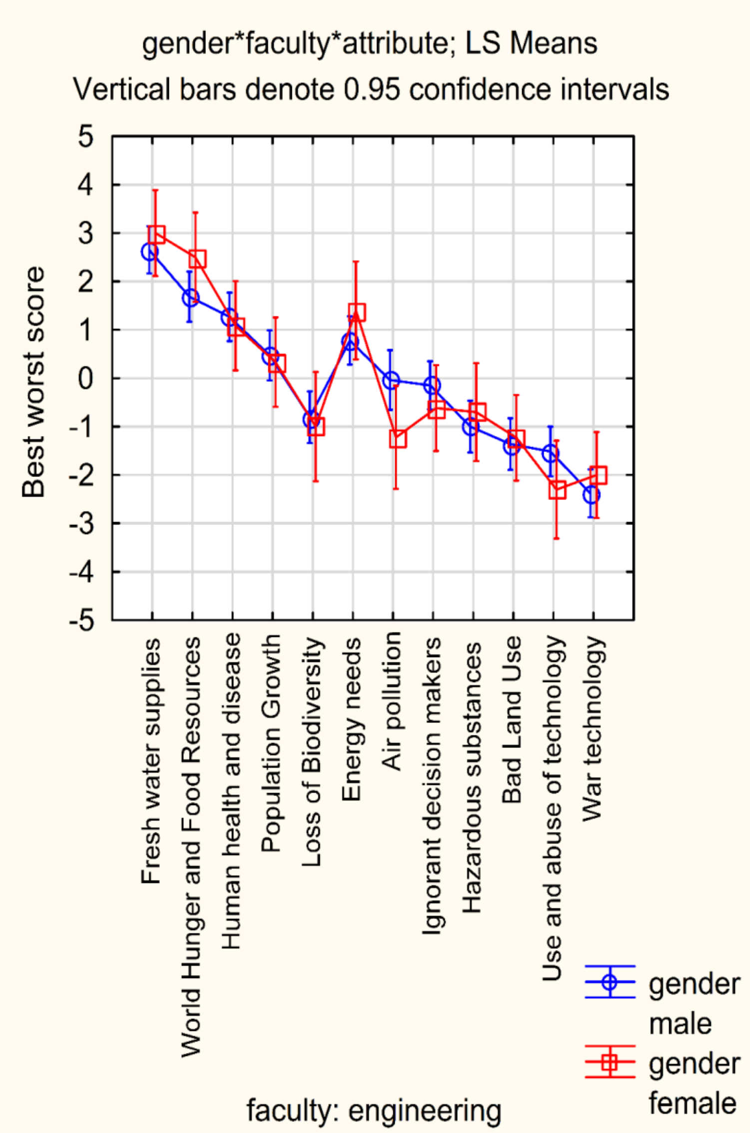

Figure 4.2: Line graph indicating the best-worst rankings of the fourth-year engineering students when the different scores achieved by the different genders were compared at Stellenbosch University in 2016.

Hypothesis 2 – that there are no significant differences between the mean ranking scores of female engineering students and male engineering students on the RLGPI (individual items) – was supported. There is no significant difference between female engineering students and male engineering students with respect to their mean ranking score on each of the 12 major science- and technology-related global problems, taken individually.

The most noteworthy difference between the two genders at the engineering faculty was the item *Air pollution*, but even this had only a P value of 0.06, which does not indicate a statistically significant difference. This result could be due to the fact that the female sub-sample in this study was a very small (n=13) and that male sub-sample was much larger (n=43). The differences in the sizes of the sub-samples should be kept in mind when making inferences about the findings of study. It suggests that it might be helpful to obtain further corroborative data from all female engineering students in the Faculty of Engineering at Stellenbosch University, or all female civil engineering students in South Africa in a further study. The fact that there were no significant differences between how male and female students ranked all of the items on the RLGPI could indicate that the type of person who studies engineering might have the same priorities when it comes to world problems, regardless of their gender. This could also indicate that the discipline of civil engineering might have a big influence on students' priorities when ranking the 12 items on the RLGPI. This, however, needs to be tested in further studies with larger samples. The top four ranked items of the female fourth-year engineering students and the male fourth-year engineering students all relate to basic human needs for long-term survival such as: *Fresh water supplies, World hunger and food resources, Human health* and *Disease and energy needs*.

4.3.3) Null Hypothesis 3 (Female fourth-year education students compared to male fourth-year education students)

Ranking	**Male education**	**Female education**
1st place	Population growth	World hunger and food resources
2nd place	Loss of biodiversity	Fresh water supplies
3rd place	Fresh water supplies	Human health and disease
4th place	World hunger and food resources	Loss of biodiversity
5th place	Human health and disease	Population growth
6th place	Energy needs	Air pollution
7th place	Ignorant decision makers	Energy needs
8th place	Hazardous substances	Ignorant decision makers
9th place	Air pollution	Hazardous substances
10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	Use and abuse of technology

12th place	War technology	War technology

Table 4.4: The way that fourth-year education male and education female students ranked the 12 science- and technology-related global problems listed on the RLGPI.

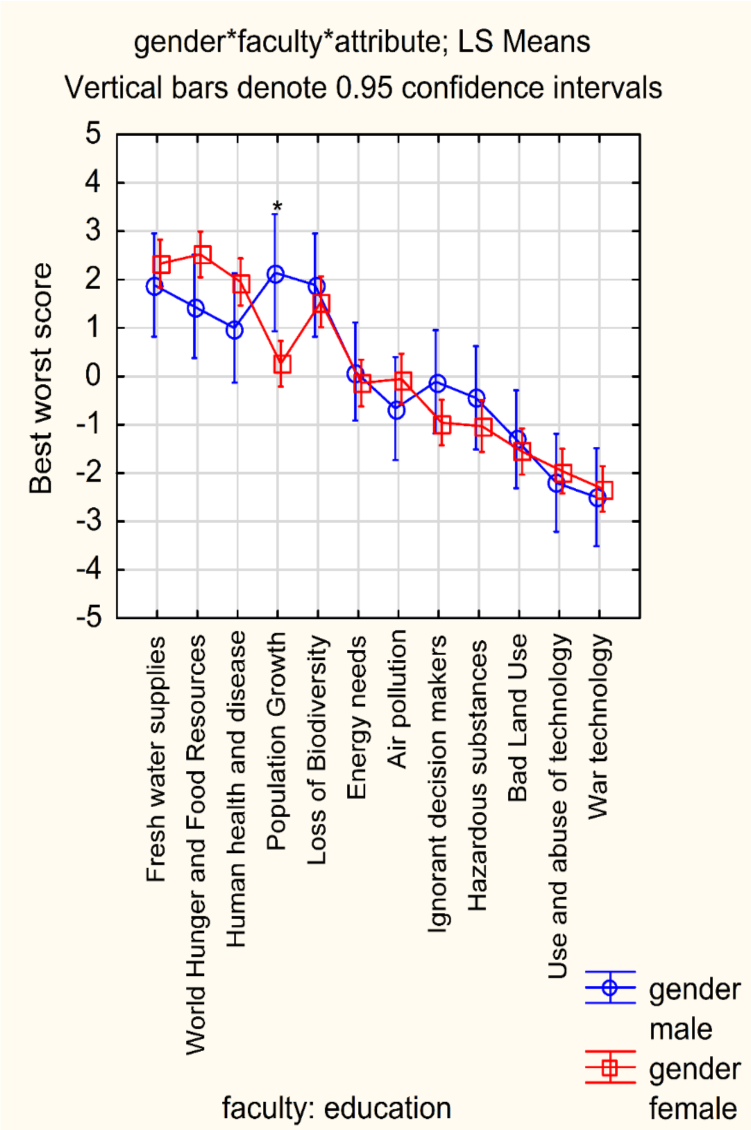

Figure 4.3: Line graph indicating the best-worst rankings of the fourth-year education students when the different scores achieved by the different genders were compared at Stellenbosch University in 2016.

Hypothesis 3 – that there are no significant differences between the mean ranking scores of female education and male education students on the RLGPI (individual items) – was not supported. There were significant differences between mean scores on some of the individual items.

There was a significant difference between the female education students and male education students with respect to their mean ranking scores on one of the 12 major science- and technology-related global problems, taken individually. There was a small male education students sample (n=10) and a large female education students sample (n=48). The small male education sample size should be kept in mind when interpreting these results. A difference between female education students and male education students of their rankings of *Population growth at a* ($p<0.01$) level. Male education students ranked *Population growth* as their 1st priority, whereas female education students ranked it as their 5th priority. In Chapter 5 we discuss this phenomenon and the reasons behind it. Gender difference could have a big influence on students' rankings because of the influence of different societal roles of men and women in the workplace and in the world. Women might become emotionally involved when ranking these problems, therefore *Loss of biodiversity* as a high priority (because they care about animals and plants emotionally) and *Population growth* as a lower ranking, because women care about families and children and they don't see more children and families as a global problem (Zaidi, 2010). But further discussion is needed and is undertaken in the next chapter, Chapter 5.

4.3.4) Null Hypothesis 4 (Female fourth-year engineering students compared to female fourth-year education students)

Ranking	Female education	Female engineering
1st place	World hunger and food resources	Fresh water supplies
2nd place	Fresh water supplies	World hunger and food resources
3rd place	Human health and disease	Energy needs
4th place	Loss of biodiversity	Human health and disease
5th place	Population growth	Population growth
6th place	Air pollution	Ignorant decision makers
7th place	Energy needs	Hazardous substances
8th place	Ignorant decision makers	Loss of biodiversity
9th place	Hazardous substances	Air pollution

10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	War technology
12th place	War technology	Use and abuse of technology

Table 4.5: The way that fourth-year female education and fourth-year female engineering students ranked the 12 science- and technology-related global problems listed on the RLGPI.

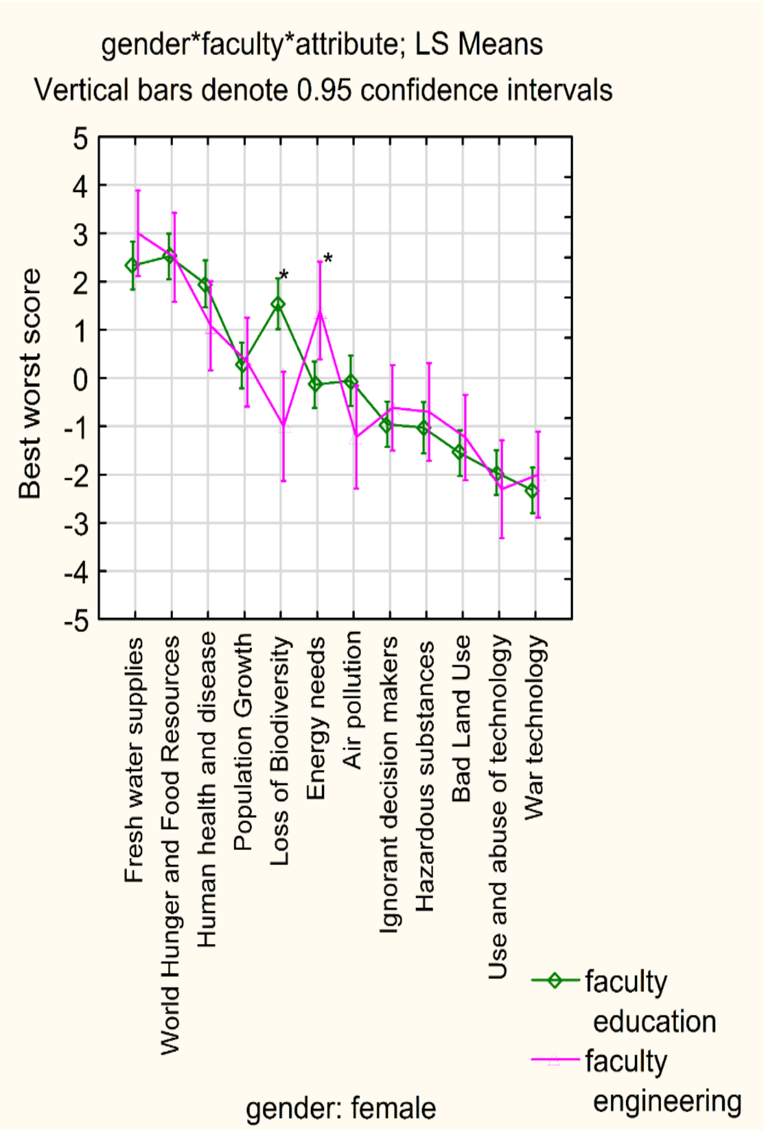

Figure 4.4: Line graph indicating the best-worst rankings of the female fourth-year education students and female fourth-year engineering students when the different scores achieved by the different faculties were compared at Stellenbosch University in 2016.

Hypothesis 4 – that there are no significant differences between the mean ranking scores of female engineering students and female education students on the RLGPI (individual items) – was not supported. There were significant differences between mean scores on some of the individual items.

There were significant differences between female engineering students and female education students with respect to their mean scores on 2 of the 12 major science- and technology-related global problems, taken individually.

The most significant differences between the two samples were on the items *Energy needs* and *Loss of biodiversity,* with female education students ranking *Loss of biodiversity* at 4th place and engineering females ranking it at 8th place ($p<0.01$). Education females ranked *Energy needs* at 6th place and engineering females ranked it at 3rd place ($p<0.01$). The finding might have been influenced by the small sample size ($n=13$) of female engineering students. However, the fact that *Energy needs* were ranked so highly by engineering students could mean that this item is more aligned with the interests of engineering students than with the interests of the education students.

4.3.5) Null Hypothesis 5 (Male fourth-year engineering students compared to male fourth-year education students)

Ranking	Male engineering	Male education
1st place	Fresh water supplies	Population growth
2nd place	World hunger and food resources	Loss of biodiversity
3rd place	Human health and disease	Fresh water supplies
4th place	Energy needs	World hunger and food resources
5th place	Population growth	Human health and disease
6th place	Air pollution	Energy needs
7th place	Ignorant decision makers	Ignorant decision makers
8th place	Loss of biodiversity	Hazardous substances
9th place	Hazardous substances	Air pollution
10th place	Bad land use	Bad land use
11th place	Use and abuse of technology	Use and abuse of technology

12th place	War technology	War technology

Table 4.6: The way that fourth-year male education and fourth-year male engineering students ranked the 12 science- and technology-related global problems listed on the RLGPI.

Hypothesis 5 – that there are no significant differences between the mean ranking scores of male engineering students and male education students on the RLGPI – was not supported. There were significant differences between mean ranking scores on some of the individual items: *Population growth* and *Loss of biodiversity.*

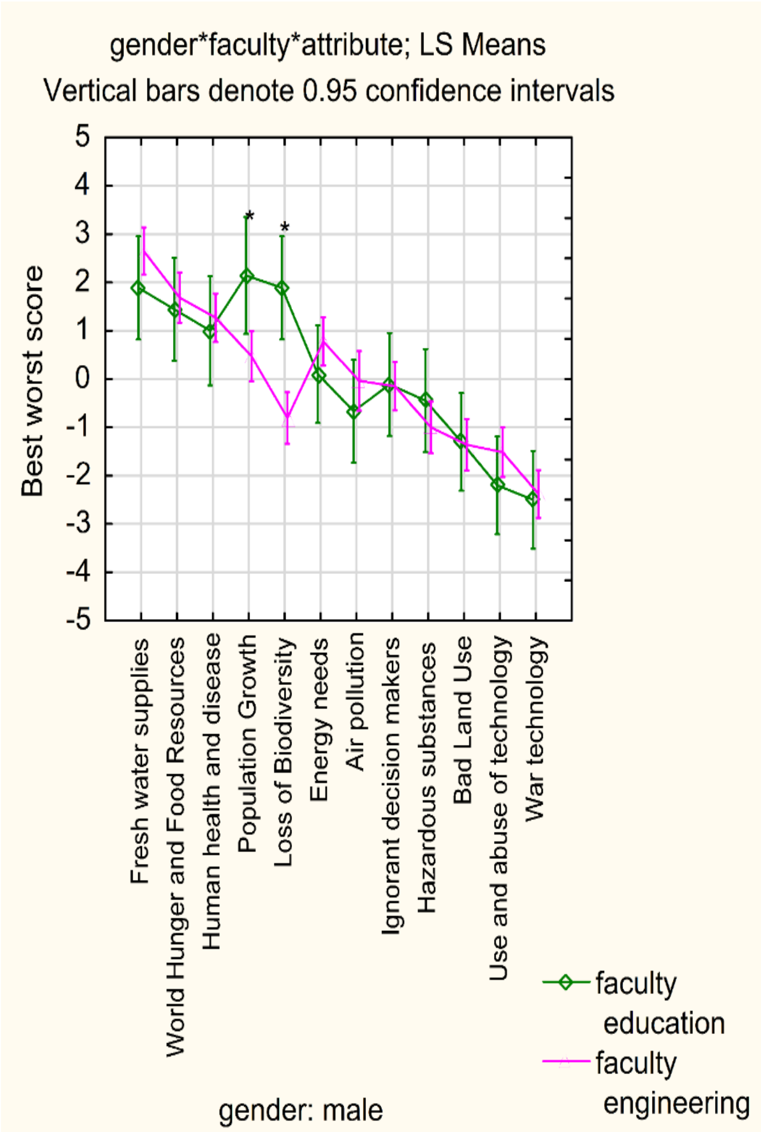

Figure 4.5: Line graph indicating the best-worst rankings of the male fourth-year education and engineering students when the different scores achieved by the different faculties were compared at Stellenbosch University in 2016.

There was a significant difference between male engineering students and male education students with respect to their mean ranking scores on two of the 12 major science- and technology-related global problems, taken individually. *Loss of biodiversity* and *Population growth* were the two top-ranked items for male education students, while male engineering students rated *Loss of biodiversity* at 8th place and *Population growth* at 5th place respectively. There is a significant difference between the male engineering and education students' rankings of *Population growth* and *Loss of biodiversity* ($p<0.01$).

There might be some limitations on the interpretation of this data because of the small size of male students in the education sample (n=10). Nevertheless, the male education students ranked two of the major current global problems as their highest priority. Usually people tend to choose priorities that are based on introspective decisions and problems that are relevant to the respondents' local context, or to their basic needs, which makes this worth investigating. This could indicate that education students discipline of study does have an impact on their priorities, since biodiversity and population growth are two topics often discussed in their course at university (Stellenbosch University, 2014). The difference in the ranking of biodiversity is also consistent with the finding on the comparison of female education and engineering students. The fact that engineering students ranked *Energy needs* as their fourth highest priority could indicate that the discipline of the engineering might have an impact on how students prioritise certain items, since *Energy needs* is a highly prioritised topic in the engineering curriculum (Stellenbosch University, 2013). This finding is also consistent with the finding when female engineering students were compared with female education students. This matter will be discussed more fully in the next chapter.

4.4 Qualitative interpretation of results

4.4.1 Analysis of qualitative questions

To supplement the findings of the quantitative component of the questionnaire, a qualitative component was added to the questionnaire in the form of three questions. This was done to elicit more detailed information. The questions asked focused on respondents' reasons for choosing the top three science- and technology-related global problems; the modes of exposure to these items, for example, social media, school, YouTube, etc.; whether these science- and technology-related global problems formed part of their curriculum at university. Responses to the qualitative questions were subjected to a content analysis aimed at identifying the main themes or trends that emerged. The findings of this analysis are presented in the tables which follow.

Education	Engineering
Concerns about and for the Earth	
The education students seem to be very concerned about the health of the earth and nature in general; here are some examples of student's responses to this question: "More nature orientated and concerned, as the preservation of Earth is more important than anything else." "Loss of biodiversity and fresh water supplies are important for life on earth. It is important to solve these issues to prevent human health and diseases and world hunger and food problems." "We live in a world that moves fast and grows quickly, some of the decisions about change are not always considerate of the environment…" "The future of our planet."	The engineering students were not as concerned about the condition of nature, but rather the effects of an unhealthy ecosystem on humans: "The dramatic decrease in natural resources combined with rapid growing populations are not sustainable." "Influence that has been impacted on the environment and livelihoods."
Personal and Introspective problems about local issues	
Some of the education students answered this survey saying they ranked the problems as more important if it had a direct impact on their own life. Here are some of the students' responses: "Topics that have less of an effect on me were least important (air pollution)…" "In the community where I came from, I was exposed to these kinds of factors or living conditions."	Engineering students referred quite often to themselves and recent events in their lives and environments as reasons that influenced their rankings: "Weighing up how important I find them/value them in my life." "Recent events: having water restrictions (therefore lack of water supply)." "Jacob Zuma, open Stellenbosch, South African Rand, Rhodes must fall, Joel Manuel."

	"…our country where we have (had) great resources, infrastructure etc. Education needs attention in this country, it will solve so much of the problems we have." "My personality and where I come from." "Current political situation in my country."
Reasons involving the human race and global problems	
Education students caring for the human race was very evident in their responses to this question: "They are my top priorities because it affects the survival of humankind." "The future of human kind and sustainably developing and managing our resources." "There is a lot of people around the world that suffers from hunger and a shortage of clean water, which influences the health of humankind."	Engineering students' interest in other people and the global population had quite an impact on their rankings of the 12 global problems: "Current trends in population growth, world economic activity and global warming." "I care about the well-being of others. I think that everyone deserves the basic needs such as food and water." "Morals/values, care for humanity and placing most value on human lives." "Human health is more important than the increase in modern technology."
Ignorant decision makers/ government	
An interesting new theme that emerged in this study was the concern students had with leadership. Education students showed some frustration with the government and the impact leadership would have on the world and South Africa: "There are certain concepts which I feel are more important because if they can be sorted out then others will too. For example, if we change the way ignorant people think then many of the other issues can be dealt with." "The things that influenced me is the current state the country is in. The land (agriculture) is not being used correctly and the government has no sense whatsoever on how to make decisions."	Engineering students were far more concerned about leadership than the education students. There were several references to ignorant decision makers and bad government, especially in South Africa. It became evident that engineering students feel good leadership and a good government will be the best solution to these problems: "The state of our country. Fresh water can be planned for and energy as well as land use, but if the lands leaders don't make the proper final decisions, it will have been for nothing." "Currently most of these are caused by poor & uneducated decision making. Countries like Austria have little resources, but are run well thus they have the least polluted countries. They have excellent health care education and no one who lives there are homeless."

	"Bad leadership leads to bad planning etc. But good leadership can change the world." "Given the current economic, social and cultural status, *Ignorant decision makers* is the top priority. Regardless of the potential a country might have, the first step to progress / change / growth is the decisions that are made by those who are elected to lead the transition from ignorance to understanding is through knowledge / discovery, this is the cornerstone required from which progress is achieved."

Table 4.7: Emerging themes from the qualitative data from the fourth-year education and engineering students at Stellenbosch University, 2016.

	Engineering	Education
News	22	16
University	21	24
Social media	11	27
Television	11	24
Friends	5	11
School	8	30
YouTube	7	4

Table 4.8: Number of times participants mentioned the items that influenced their priorities gathered from the quantitative data from the fourth-year education and engineering students at Stellenbosch University, 2016

	Engineering	Education
Fresh water supplies	20	5
Energy needs	19	10
Pollution	18	6

Use and abuse of technology	11	13
Population growth	8	14
Loss of biodiversity	6	18
World hunger and food recourses	1	10
Human health and disease	0	6

Table 4.9: Number of times participants mentioned the topics discussed in their course at university, gathered from the quantitative data from the fourth-year education and engineering students at Stellenbosch University, 2016.

4.5 Findings of overall results

The following observations were based on the results of the questionnaires and the qualitative questions gathered from participants.

The results reveal that the overall differences in rankings between the fourth-year education students and fourth-year engineering students were not significant, except for *Loss of biodiversity* and *Energy needs*, where differences were evident at the $p<0.01$ level. Both samples ranked *Fresh water supplies, World hunger and food resources* and *Human health and disease* as their top three priorities. The top-ranked item for engineering students was *Fresh water supplies*. The top-ranked item for education students was *World hunger and food resources*.

Gender differences for the whole group of fourth-year education and engineering students revealed that males ranked *Fresh water supplies, World hunger and food resources* and *Human health and disease* as their top priorities. Female students also ranked these three items as their top priorities. The item *Fresh water supplies* was the engineering students' top priority and *World hunger and food resources* was the education students' top priority. *Loss of Biodiversity* was one of the items where the ranking between males and females for the whole group differed at a statistically significant level; males ranked *Loss of biodiversity* as their 8th most important priority and females ranked it as their 4th most important priority. These results are represented in Table 4.3.

Responses gathered from the qualitative data revealed that students perceived their priorities of science- and technology-related global problems to have been influenced by television, social media, university and school. Most of the engineering students said problems discussed in the news, at university and on social media had an influence on their choice of rankings. Education students' rankings were mostly influenced by school, social media, television and university. Eighteen respondents from the education faculty mentioned *Loss of biodiversity*; this could support the claim that students' priorities are influenced to some extent by their curricula (Table 4.8).

Twenty-four education students and twenty-one engineering students mentioned that they were exposed to the 12 items on the RLGPI from their course at university and this could support the claim that students' field of study could have an impact on their rankings of the 12 items of the RLGPI. Thirty education students claimed they were exposed to the 12 items on the RLGPI at school. This supports the claim that students' priorities are influenced to some extent by what they learn in their school curricula. Twenty engineering students reported to have discussed *Fresh water supplies*, 19 reported to have discussed *Energy needs* and 18 reported to have discussed *Pollution* in their course at university. These results support the claim that students' priorities are influenced to some extent by their curricula that form part of their courses at university. These data are represented in Table 4.8.

There were some themes that emerged from the first qualitative question (in Table 4.7). A prominent theme that emerged among the engineering students was related to the item *Ignorant decision makers*, which was ranked relatively highly at 6th place. Students thought that many of the science- and technology-related global problems could be ameliorated by better governance and education. One student wrote:

Given the current economic, social and cultural status, *Ignorant decision makers* is the top priority. Regardless of the potential a country might have, the first step to progress / change / growth is the decisions that are made by those who are elected to lead the transition from ignorance to understanding is through knowledge / discovery, this is the cornerstone required from which progress is achieved.

Education students' care for the human race and concerns about global problems influenced their ranking of the items on the RLGPI. As one student noted: "They are my top priorities because it affects the survival of humankind." Concern about and for the Earth was also one of the biggest motivations for many of the education students' rankings. As one student wrote: "More nature orientated and concerned, as the preservation of Earth is more important than anything else."

Personal and introspective problems regarding local issues was a theme that emerged from the qualitative questions, especially among the engineering students. As one student stated: "Weighing up how important I find them/value them in my life" and "Current political situation in my country."

The implications of these findings will be discussed more fully in Chapter 5.

4.6 CHAPTER SUMMARY

This chapter presented and analysed the results of the survey. Five null hypotheses were tested and shown to be either supported or rejected. An explanation and discussion of the emerging significant differences are presented in the next chapter.

CHAPTER FIVE:
DISCUSSIONS OF RESULTS

5.1 MEETING BASIC NEEDS THROUGH THE SCIENCE CURRICULUM

The education students from Stellenbosch University all placed *Fresh water supplies, Population growth, Human health and disease, Loss of biodiversity* and *World hunger and food resources* as their top-ranked items. This is consistent with findings over a 23-year period from samples from disparate subject disciplines and in different countries. The education students ranked *World hunger and food resources* as their top priority. The top-ranked items relate to basic human needs for short- and long-term survival, such as *Loss of biodiversity*, and these ratings provide empirical evidence to support the importance of meeting the basic human needs of society as a whole. These priorities also coincide with the United Nations 17 sustainable development goals (United Nations, 2016). The RLGPI and the United Nations 17 goals are similar; even though their naming is a bit different, each name still signifies the same topic: *Poverty and hunger* is represented as *World hunger and Food resources*, *Good health and well-being* is represented as *Human health and disease*; *Clean water and sanitation* is represented as *Fresh water supplies*; *Affordable and clean energy* is represented as *Energy needs*; *Infrastructure* is represented as *Bad land use*; *Climate action* is represented as *Air pollution*, and *Life below water* and *Life on land* is represented as *Loss of Biodiversity* (United Nations, 2016). Similar priorities on the RLGPI align with the goals set by the United Nations Environment Programme (UNEP) in the conservation of biodiversity and sustainable development (Secretariat of the Convention on Biological Diversity, 2014).

In early 2013 the South African government introduced the National Development Plan (NDP)-2030 as the country's long-term socio-economic development roadmap. The NDP is viewed as a policy blueprint for eliminating poverty and reducing inequality in South Africa by 2030. In order to address the country's socio-economic imbalances, the NDP identifies the key constraints to faster growth, among other things, and presents a roadmap to a more inclusive economy. The findings of this study indicate that students' priorities are aligned in some ways with those of the NDP. According to the NDP, climate change has the potential to reduce food production and the availability of portable water, with consequences for migration patterns and levels of conflict. Fighting poverty and providing better education are among the NDP's main goals, as in the RLGPI, as well as fighting corruption (National Planning Commission, 2011). Students ranked priorities similar to these goals as very important such as, *World hunger and food resources*, *Fresh water supplies*, while engineering students focused on *Ignorant decision makers* (which includes dealing with corruption).

The engineering students from Stellenbosch University all placed *Fresh water supplies, Population growth, Human health and disease, Energy needs* and *World hunger and food resources* as their top-ranked items. This is consistent with findings over a 23-year period of samples from disparate subject disciplines and in different countries. The engineering students ranked *Fresh water supplies* as their top priority. The top-ranked items relate to basic human needs for short- and long-term survival, such as *Loss of biodiversity*, and these rankings provide empirical evidence to support the importance of meeting the basic human needs of the South African population. How students rank science- and technology-related problems could also be influenced by the immediate challenges faced by a country and what is privileged in the curriculum. The qualitative data suggest that the drought in South Africa in 2016 had an influence on students' choices. This, together with the privileging of problems related to water-related matters in the civil engineering curriculum might in part explain why civil engineering students ranked *Fresh water supplies* as their top-ranked item.

Follow up studies will be needed to provide corroborative evidence in this regard. It is clear that even when respondents are asked to focus on a human problem in its global context, there appears to be an introspective tendency instead to regress to perceiving the problem more in its local and even personal context, if it is regionally acute at that time.

Problems like ignorant decision makers in political leadership are a source of worry for people in their local context, even if there are bigger problems such as global warming and war technology. In the public debate about corruption South Africa was supposed to have solved its problems in 1994, after apartheid had ended, and start over with a clean state. However, Friedman (2015) argues that corrupt politicians continued to govern and began to loot the wealth that well-organised companies and hard-working middle-class citizens created. And this strengthens the stereotype of corrupt African politicians inevitably wrecking their societies (Friedman, 2015). Citizens of South Africa are constantly faced with problems in their immediate environment caused by poor government and ignorant decision makers. This provides a possible explanation for why engineering students might have prioritised a local problem as very important (they ranked *Ignorant decision makers* in 6th place), even though the concern might be insignificant in the global context.

Another problem to consider is *Energy needs*. It a very important problem in the local context of South African citizens, because of the current social-political circumstances and problems such as Eskom and load shedding in South-Africa, and the government not being able to provide enough energy for its citizens (Greenpeace, 2012). This will be discussed in greater depth in the next section.

5.2 IMPLICATIONS OF THE DIFFERENCES AND SIMILARITIES FOUND BETWEEN GENDER AND FACULTY.

The implications of the differences between the female students and male students will be discussed in this section, as well as the implication of the differences between the different faculties (engineering and education).

In these results it became evident that there might be some differences in prioritisation that are related to students' genders. Many of the conclusions about gender intersect with students' field of study because the education sample is predominantly female and the engineering sample predominantly male. Gender and field of study can therefore not be easily disaggregated.

In the sample with fourth-year engineering students and fourth-year education students there were two statistically significant differences between their rankings of the global problems. There was a significant difference between the ranking of *Energy needs* and *Loss of biodiversity*. These results could indicate that, because the engineering students are predominantly male, the rankings could be influenced by their gender. The engineering students could also have considered *Energy needs* as a very important problem, because of their curriculum and the current social-political circumstances and problems such as Eskom and load shedding in South-Africa, and the government not being able to provide enough energy for its citizens (Greenpeace, 2012). South Africa's dominant energy security perspective is still rooted in the narrow-minded focus on stocks of unrenewable energy resources, the economy as an energy user and independence from oil imports (Hedden, 2015). However, the challenges facing South Africa's energy system are not as simple as this technical, 'input-output' approach would suggest. Hedden (2015) describes how over the last 20 years South Africa has failed to make the necessary investments in major required energy infrastructure developments. Also, there is an enormous backlog in infrastructure development and a very apparent investment paralysis. While there have been some substitute measures and some victories, these are very rare. It is disconcerting that these concerns cannot be addressed directly through clear policy, legislation and regulation to implement the policy. Even when final policy statements have been made at the highest-level, implementation has been the biggest problem:

This is evidenced in the shortages in bulk electricity supply, the growing backlog and on-going deterioration of electricity redistribution infrastructure, poor households' energy insecurity, discontinuities in coal supply, the absence of a credible liquid fuels policy, and comparatively low crude oil stocks. The security of the system has been compromised to the point of crisis. Increasing dysfunction coupled with the continuation of previous approaches to the problem, despite previous failures and without contingency measures, makes the system's endurance going forward uncertain (Trollip, Butler, Burton, Caetano, & Godinho, 2014, p. 27).

Engineering students might feel this is one of the problems they could fix and become involved with, because of their power and interests as engineers.

The education students are predominantly female and this could have an influence on their rankings of the global problems, because of their caring nature (Sevon, 2005). Therefore, females could feel *Loss of biodiversity* is a very important priority, even though they might not be able to solve this problem themselves. In the education curriculum that they follow they could also be influenced to think about biodiversity and how it affects all humans on earth as well. There is a big part of the Life Sciences school curriculum and education students would have been exposed to this as part of initial teacher education courses. One of the unwritten rules of animal social behaviour is that females tend to be the caring sex, while males focus more on mating (Queller, 1997). In nature there is a better chance that a female will become a parent, than the chance of a male becoming a parent (Queller, 1997). Evolution always favours the sex who is more caring in the beginning of the offspring's life, to possibly be a parent (Fromhage, Jennions, & Kokko, 2016). The female might end up being the only one caring for the offspring (Fromhage, Jennions, & Kokko, 2016). This comes down to the fact that males have more sperm than females have eggs; therefore it is often difficult for a male to be certain that he is the father, so males might, at the start, care a little less for the offspring (Fromhage, Jennions, & Kokko, 2016). This can be the reason for females being more caring towards animals, people and plants. Women have a need to care for children and a 'need to nurture' (Sevon, 2005). Even though giving birth is not a biological requirement for a woman, motherhood is fixed within the female embodiment (Sevon, 2005).

The fact that both faculties ranked *Fresh water supplies* as their most important priority might be understood in the context of the severe drought that has gripped South Africa over the past year (Pimentel, Berger, Filiberto, Newton, Wolfe, Abbet, Nandagopa, 2004). There have even been water restrictions for residential use in some regions, even in Stellenbosch (Pimentel et al., 2004). Water scarcity is different from water shortage or water stress. Hedden and Cilliers (2014) discussed the water shortage situation in South Africa: the water shortages that can occur in South Africa are characterised by low and variable annual rainfall along with high natural evaporation levels, making it the 30th driest country in the world. The average yearly rainfall in South Africa is only 495 mm, whereas the average in the world is 1 033 mm (Hedden & Cilliers, 2014). The lack of water is often more the result of evaporation than from poor rainfall. Furthermore, the little rain that falls is unevenly distributed, with some regions receiving less than an average of 100 mm of rain in a year. The National Development Plan notes that "since South Africa is already a water-scarce country, greater attention will have to be paid to the management and use of water." Areas providing water in the Mpumalanga Highveld coalfields, upstream of the Vaal and Loskop dams and in the Lephalale-Waterberg area, are at risk of water pollution, because of the water intensive mining industry and the large amounts of water used in the process of the combustion of coal (Hedden & Cilliers, 2014). It is encouraging to see that both education and engineering students ranked water as their top-ranked item, given that South Africa is a water-scarce country and because further droughts can be expected in Southern Africa because of climate change (Mekonnen & Hoekstra, 2011).

Zaidi (2010) gives a simple example of how our brains determine why women feel differently than men about things, even if they come from the same background:

The fundamental neurological substrate that forms the basis for complex cerebral asymmetries in Homo sapiens may have been established remarkably early in anthropoid evolution. In ancient times, both sexes had very defined roles that helped ensure the survival of the species. Cave-men hunted while Cave-women gathered food near the home and cared for the children. Brain areas may have been sharpened to enable each sex to carry out their jobs. In evolutionary terms, developing superior navigation skills may have enabled men to become better suited to the role of hunter, while the development by females of a preference for landmarks may have enabled them to fulfil the task of gathering food closer to home. The advantage of women regarding verbal skills also makes evolutionary sense. While men have the bodily strength to compete with other men, women use language to gain social advantage, such as by argumentation and persuasion (pp. 46-47).

Our brains are genetically different and this could influence rankings of priorities, such as *Population growth*, in this instance (Zaidi, 2010). Generally females who study education could be influenced by their culture, gender and society that probably does not expect them to have children, so they might rate population growth as a lesser problem (Luthar, 2003). The biggest drivers of low birth rates are modern Western values, which favour the education of women, women in the workforce, easy availability of contraception and so on (Sevon, 2005). Normally affluent mothers do not work outside the home; despite exceptional credentials and often ambitious early career goals, many of these women leave their jobs once they are mothers (Luthar, 2003). As a result, they often miss out on numerous job-related fulfilments, "including the self-efficacy and positive identity that derive from jobs well done and the vital networks of supportive relationships and sense of community that can be accessed in the workplace" (Luthar, 2003, p. 1587). Woman might not see *Population growth* as very important, because women from various socio-economic strata tend to prefer being in the office to staying at home to care for young children, because taking care of children seems more stressful (Luthar, 2003). The women in this study are also likely to be career women and may therefore want few children. Some women could therefore have responded to the item from a personal perspective rather than taking a global view.

There is a possibility that men might be able to look at *Population growth* as a global problem. In many countries such as in Germany men are simply saying no to having children (Blake, 2013). The research suggest that men in Germany don't want to complicate their lives by having babies; neither do they want to quit their jobs to raise a child and they don't want their wives to do so either (Luthar, 2003). Research also suggest some men, as in Germany, see population growth as a major problem for the future and they prefer to reduce their worries by not having any babies; also the economic prospects of having children don't look so good (Blake, 2013). Some men also claim that the current issues of immigration and refugees made them realise the impact of having more children could have a negative effect on the world (UNICEF, 2015).

Research has been done on the human brain to try and explain gender differences in the function and structure of the brain (Zaidi, 2010). The left side of the male brain is bigger than the right side (the left side of the brain is used for logical thinking) (Zaidi, 2010). The two hemispheres of the male brain are further apart than in a female brain (Zaidi, 2010). This has the implication of woman using the whole brain during decision making, whereas men use one side of the brain (Zaidi, 2010).

Boys generally demonstrate superiority over female peers in areas of the brain involved in math and geometry. Females tend to think more observantly and women tend to be more observant. Men tend to be more logical emotionally. They tend to put importance on their feelings and observations about a situation (Zaidi, 2010, p. 43).

Because of this, woman think logically and emotionally at the same time, whereas men use only the left or the right side at a time. Consequently doing problem solving in a survey such as the RLGPI would probably only involve logical thinking for the men, without any emotional connection. Women, on the other hand, might become emotionally involved when ranking these problems, therefore *Loss of biodiversity* has a high priority (because they care about animals and plants emotionally) and *Population* *growth* has a lower ranking, because they care about families and children and they don't see more children and families as a global problem (Zaidi, 2010).

In the Education Faculty participants indicated that their own insight and care for humanity influenced their decisions. Some indicated that the current electricity crisis in South Africa also influenced their choices. One of the more prominent reasons was the drought and lack of water for farmers in the Western Cape, which influences everyone directly, because this exacerbates world hunger.

From a gender perspective most girls indicated that their nurturing nature and their care for the human race influenced their decision, while most boys indicated that the current lack of water and the growing electricity needs influenced their decision, as well as a corrupt and uninformed government that is not able to solve these problems (poor decision makers). This creates a framework for understanding the challenges that individuals face in societies. Some societies that are patriarchal and heteronormative discriminate on the basis of sexuality and gender (Nel, 2014). These kind of problems could make it difficult for woman to follow her career choice, because of her gender. Consequently there needs to be a concerted effort to break these barriers that society has constructed.

Integrating women as equals into the workforce was a struggle long before the start of the feminist movement. But since then women have been allowed into more hazardous forms of work. But the role of women in the family and the specific requirements of women in the local labour market still remain unclear (Howcroft & Richardson, 2008). Current debates on globalisation of the economy tend to place the emphasis on the role that woman play in the workplace. Emphasis is also placed on the new clusters of scientific and technological innovations. With the rise of women in the workplace and scientific and technological innovations, different movements and organisations around the globe are joining together to face the challenges this might bring (Howcroft & Richardson, 2008).

The discussion above offers tentative observations and interpretations, and further studies are necessary to provide corroborative evidence.

5.3 Comparison of findings with previous research done

It was found that the rank-order correlation between the 1993 engineering undergraduates' priorities and the 1984 international science educators' priorities was 0.65. Between the 1993 engineering undergraduates' ratings and the 1993 Cape Town science educators' ratings, the correlation is 0.85. These are significantly high correlations reflecting a high degree of consistency over a 10-year period on the same set of issues.

The findings of a survey in 1995 of 946 South African science pupils largely match the findings of the 1993 survey of 76 Western Cape science teachers on the original Bybee scale. The top-ranked items of the teachers were *Human health and disease, Population growth, World hunger and water resources*, which fully corroborates the findings of this study. The three items that had a low priority for the 76 teachers were *Mineral resources, War technology* and *Nuclear reactors* (Le Grange, 1996). The same three items also had a low prioritisation for the samples in this study.

The same study with secondary school pupils indicated that students were aware of the importance of clean water as a natural resource. The provision of *Fresh water supplies* was ranked first, third and fifth by samples 1, 2 and 3 respectively (Le Grange, 1996). This is a clear indication that 11 years later *Fresh water supplies* remains an important problem for people in South Africa in 2016.

In a previous study by Le Grange, Rochford and Sass (1996) male and female engineering and business/marketing students all ranked *Mass housing, Fresh supplies, Population growth, Human health* and *World hunger* highly. The top-ranked items related to basic human needs for long-term survival, and these ratings provide empirical evidence to support the importance of meeting the basic needs of the South African population (Le Grange, Rochford, & Sass, 1996). *Mass housing* was the only item that did not appear in this study of 2016, because this item was not listed on the RLGPI.

The dangers of *Artificial intelligence*, which formed part of the item *Use and abuse of technology*, might have been ranked as one of the lowest items, because people don't experience it as a threat in their day-to-day lives, or on the news or social media. *Artificial intelligence* doesn't seem to have a higher priority than basic human needs.

Currently trending in the news are issues such as the drought across the country (Claassens, 2016), problems in politics (Mkokeli, 2016) and protestors at universities (Letsoalo, 2016); headline news of a threat from artificial intelligences is not evident. Current research also suggests adapting the kind of intelligence these machines would have. By making these artificial intelligence machines socially aware (to work within the interests of society), we could make artificial intelligence work for us and not against us.

Priority is given to affective and social responses that serve to engage the whole agent in the life of the communities in which it participates. Intelligence is seen not as the deployment of capabilities for problem solving, but as constructed by the continual, ever-changing and unfinished engagement with the social group within the environment (Clocksin, 2003, p. 1721).

Reassurances such as these that artificial intelligence might not be a serious threat could also be a reason for the its low ranking of importance.

5.4 Implications and conclusions

Society and government have to recognise that it is vital for the improvement of society as a whole, to supply superior scientific education for all citizens. The much needed change in the school curriculum will not happen until the government aligns science education with the UN- and STS- goals of science education planning, on the national level (Robinson, Tibanyendera, & Seltzer-Kelly, 2007).

Relevant, updated science education in school is important for future engineers. This could influence their priorities and perspectives in approaching typical engineering problems in society.

What and how teachers will teach will ultimately decide what students will learn. Therefore teachers' knowledge about teaching practice and scientific literacy is of utmost importance.

Teacher training is an aspect that is directly related to the school and classroom environment. It plays a vital role in developing teachers. In teachers' training they will be exposed to the elements and information they will use to educate their students. Teachers' scientific literacy should be improved so they can educate students appropriately. It is critical that students are exposed to various situations that may lead to the creation of a positive school and classroom learning environment. Furthermore, students need to be exposed to currently relevant issues in the world, which is an important approach that can have a direct and positive influence on the promotion of sustainable living. This study explored the correlation between engineers' and teachers' priorities regarding science-and technology-related global problems. This study investigated whether students' interests and priorities can be influenced on the basis of the interests of the teacher giving the lesson. This study investigated whether the priorities of teachers possibly influenced students wanting to become engineers. Knowledge and priorities of the student teachers could be an indication of the priorities in the B.Ed curriculum at Stellenbosch University.

Anything from lack of knowledge, environment, culture, circumstances and attitudes influenced the ranking of priorities. The priorities measured are important, because they provide a national portrait of students' general appreciation of science, and hence a sense of responsibility towards selected science-related issues that might have national or international implications (Bybee, 2008). Bybee (2008) quotes Ophuls (1977), who says that there is a need to understand scientific ideas such as renewable and non-renewable resources and the capacity of ecosystems to degrade waste. Understanding issues of ecological scarcity directly influences economic stability and social progress (Bybee, 2008).

Le Grange (2002) says that just education alone can't fight for the environment, because of challenges of the ever growing population and the need to satisfy a developing world; always in need of more resources. Environmental education has to include ideas to protect the environment while catering for the needs of the developing economy. The goal of environmental education in the science curricula, according to Le Grange (2002), has become sustainable development. There is a tension that prevails in the world, the need to conserve and protect the environment, and society requiring social and economic development. Unfortunately, environmental education has always had some kind of struggle to find a place in the science curriculum (Le Grange, 2002). Bybee has made it his mission to improve science literacy and therefore promotes the teaching of environmental education. Through using this instrument and the results of the survey based on it, society's need for the democratisation of science can be addressed.

Bybee (2008) writes that scientific literacy is important and necessary for individuals' proper participation in society. He argues that scientific literacy helps students to make personal decisions and to think about public policies that influence their day-to-day lives (Bybee, 2008). These decisions include addressing questions about personal health, natural hazards, and acquiring information about science and technology (Bybee, 2008). Using this instrument to determine different peoples' priorities in different areas can help to develop a curriculum that is relevant and contains information about science- and technology-related problems that have a direct impact on peoples' lives.

5.5 Chapter summary

This chapter discussed the results of the survey under the sub-sections that deal with meeting basic needs through the science curriculum, the implications of the differences between gender and faculty, a comparison of findings with previous research, and implications of the findings, followed finally by conclusions. This chapter has shown the importance of the RLGPI and indicates how it can be used to benefit multiple curricula and the environment. This chapter also discussed the possibility of further research to investigate the differences in the rankings of these topics and if there are more conclusions to be drawn from the results.

CHAPTER SIX
RECOMMENDATION AND CONCLUSIONS

6.1 CRITIQUE OF RESEARCH METHOD AND RESEARCH INSTRUMENT

Non-probability survey sampling was used in this study therefore the results and conclusions are generalisations only applicable to the samples used in this specific study.

Non-parametric statistical methods could be powerful and accurate for making assumptions about a certain set of data. The data of this study have been analysed by means of non-parametric statistics, because the RLGPI is a rank-order scale. The data produced by a rank-order scale are not necessarily normally distributed, because the scales are not equal-interval scales. However, the data produced in this study might not be strong enough to apply to more than the samples in this study.

The split-half method of determining reliability and methods of determining internal consistency cannot be applied to rank-order scales. Rank-order scales have a very limited way in which reliability can be measured. The test/retest method is the most effective and successful way to measure the reliability of a rank-order scale.

The following recommendations concerning the future use of the research method and instrument are suggested. Limitations of the instrument itself is also mentioned.

Recommendation 1

When updating the RLGPI, it would be advisable that the latest science- and technology-related global problems are researched, and social media and other modes of exposure are referred to before the instrument is administered to the pilot study participants.

Recommendation 2

It is also advisable that the experts who are consulted to assist in the development and updating of the instrument are consulted personally and a conversation can be conducted about adding to the reliability of the instrument. In this conversation valuable contributions to the latest research and reality of the items on the instrument can be evaluated and discussed. The experts' personal insights on the instrument and opinions of the instrument make the research very valuable.

Recommendation 3

It is a good idea to use the RLGPI as a guideline when updating the instrument in the future. Using the same items and updating only the different descriptions in brackets can help to retain the instrument's reliability and validity, because tests on the instrument have already been done.

Recommendation 4

Using the best-worst-scaling is much more effective and makes it easy for the respondents to complete to survey. Using the best-worst-scale instead of simply the full rank-order-scale made it easier for respondents to choose their top priorities. They only had to choose from a list where items were arranged in 12 groups of 4, instead of 1 group of 12 items. Respondents could be more relaxed when choosing only their best and worst options from a shorter list.

6.2 Recommendations for further research

When doing further research, it is recommended that the instrument be administered to students electronically, if this is possible. It might be easier to distribute the survey to more students at a time and to save paper. Students only have 10 minutes to complete the survey. Encouraged to express their own thoughts. This means the rankings are given on the basis of the person's own opinions and their immediate thoughts, rather than having external influences affect their opinion. The way this survey is answered is very important, because the survey will explore the personal opinions and priorities of the specific group being tested. If the participants are influenced by external forces, the survey might not be as effective when it comes to making an assumption about the specific participants' lives.

When using this survey, it is important to mention to participants answering the survey that their personal opinions and thoughts are important, not what they think they are supposed to say. This survey is effective if participants answer this survey as it is applicable to their own lives.

Wider studies could be conducted to corroborate the findings of this study. This study could also be conducted with a stronger qualitative component adopting a full-mixed methods approach to get more valuable insights into the participants' minds and the thoughts that influenced their choices

6.3 Conclusion

In this study conducted in 2016, and in other similar surveys conducted by Le Grange and his team in 1995, the LGPI and RLGPI have proved to be convenient instruments which have produced generally consistent results across disciplines, gender and culture, and that it also reveals nuances in the data, based on gender and the discipline studied.

It might be useful to establish whether the preferences of respondents in other multicultural countries yield similar findings. The RLGPI is an up-to-date, simple, valid, adaptable and reliable instrument. It might be used to gather further response data efficiently from samples in South Africa. The RLGPI might be a useful instrument to use to identify problems created by science and technology and helping to solve them; as Piet Hein said: "We need to evolve problem solvers galore since each problem they solve creates ten problems more" (Ricketts, 2016, p. 1). Without knowledge about sets of priorities from engineering students, education students or conservation students, it might be difficult to find ways to involve people to solve these science- and technology-related problems.

The results of this survey are supported by findings over a 12 year period; the top-ranked items remain those related to the basic needs for the short-term and long-term survival of human beings (Le Grange, 1996). This survey could be a means of identifying gaps in people's knowledge and establishing what problems people are not aware of. It could also indicate certain priorities that people might have, but the government is unaware of. Curricula need to be updated constantly to address the needs of society (Bybee, 2008). Research suggests that curricula in South Africa are seriously out of date and are no longer relevant to South African students' lives as well as global problems (Tsanwani & Juta, 2016). The RLGPI can be used to make society more involved with and informed about the needs and problems in their own country and the world. Once the curriculum has been updated, students can become aware of global problems and this might inspire them to become involved in solving these problems in their future. When people are educated about certain problems in their environment and in the world, they might be more prepared to become involved in solving them.

The fact that significant local differences were found on some items between the samples indicates that people's perceptions of global problems may be modified or shaped by their own context, i.e. by their immediate environment and personal needs for survival.

Education does have an important role to play in solving global problems related to science and technology. However, in Le Grange's (1996, p. 65) study he uses a quote by David Orr (1990) that is still very relevant to this study in 2016. David Orr (1990) draws attentions to the fact that education as such is not the solution for global environmental problems. He said:

> If today is a typical day on planet Earth, we will lose 116 square miles of rainforest, or about an acre a second. We will lose another 72 miles square miles to encroaching deserts, as a result of human mismanagement and overpopulation. We will lose 40 to 100 species, and no one knows whether the number is 40 or 100. Today the human population will increase by 250 000. And today we will add 2 700 tons of chlorofluorocarbons to the atmosphere and 15 million tons of carbon. Tonight the Earth will be a little hotter, its waters more acidic, and the fabric of life more threadbare. The truth is that many things on which your and my future depend are in dire jeopardy: climate stability, the resilience and productivity of natural systems, the beauty of the natural world, biological diversity. It is, rather, largely the result of the work by people with BAs, BSs, LLBs, MBAs, and PhDs. It is not education that will save us, but education of a certain kind.

When educating people about global problems, it is not only essential that the content of these problems are taught and learned, but the method by means of which teaching and learning occurs is also important. The success of teaching methods requires a lot of exploration, but they are beyond the scope of this study. "The survey also supports a perceived need for more modern and relevant science curricula adapted to preparing a citizenry to be more critically conscious of global problems, and able to make informed decisions in a democratic society (Le Grange, 1996, p. 65).

Jane Goodall once said: "You cannot get through a single day without having an impact on the world around you. What you do makes a difference, and you have to decide what kind of difference you want to make" (Goodreads, 2016, p. 1). When we can properly educate our children about their responsibility towards each other and nature, we can start to explore the possibility of changing the world.

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APPENDIX

A) GLOBAL ENVIRONMENTAL ISSUES/PROBLEMS:

AIR QUALITY AND THE ATMOSPHERE (acid rain, CO2, depletion of ozone, global warming, etc.)

ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production, etc.)

EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity)

HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals, lead paints, etc.)

HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress, diet and nutrition, exercise, mental health, etc.)

LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, etc.)

MINERAL RESOURCES (non-fuel minerals, metallic, and non-metallic minerals, mining, technology, low grade deposits, recycling, reuse, etc.)

NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, etc.)

POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability, etc.)

WAR TECHNOLOGY (nerve gas, nuclear development, nuclear arms threat, etc.)

WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertiliser contamination, etc.)

WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation, etc.)

B) (LGPI) LE GRANGE GLOBAL PRIORITIES INSTRUMENT:

RANKING OF SCIENCE AND TECHNOLOGY –RELATED GLOBAL PROBLEMS

What do you see as the most important global problems related to science and technology for the human race? Rank the following from 1 to 15 (With 1 indicating your top priority). Insert your numbers in the appropriate brackets.

GLOBAL (WORLD) PROBLEM

[ ] THE PROVISION OF MASS HOUSING FOR HUMAN BEINGS (homes for all including garbage collection and sewage disposal, shelter, protection, street lighting, social services such as police force and postmen).

[ ] UNSAFE SUBSTANCES (waste dumps, poisonous chemicals, lead paints, electromagnetic wave radiation from the sun and microwave oven radiation).

[ ] HUMAN HEALTH AND DISEASE (catching and non-catching disease such as AIDS, exercise mental health, stress, noise, diet and nutrition).

[ ] MINERAL RESOURCES (non-fuel minerals, metallic and non-metallic minerals, mining, technology, low grade deposits, recycling, refuse).

[ ] FRESH WATER SUPPLIES (waste disposal, river mouths, water supply and distribution, ground water contamination, fertiliser contamination, waste water treatment, prediction and control of floods and droughts).

[ ] POPULATION GROWTH (increase in world population, immigration, living space, town planning).

[ ] EXTINCTION OF PLANTS AND ANIMALS (fewer types of animals remaining, over-fishing, pollution and reduction of life in the oceans, wildlife protection).

[ ] ENERGY SHORTAGES (human manufactured fuels, solar power, fossil fuels, fewer resources, conservation, oil production).

[ ] WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear weapons threat).

[ ] AIR POLLUTION (acid rain, CO2, depletion of ozone layer, smoky smog, global warming).

[ ] WORLD HUNGER AND FOOD SUPPLIES (food production, crops and agricultural methods).

[ ] BAD LAND USE (soil erosion, reclaiming of land, city spread and growth, wildlife habitat loss, removal of forests, spreading of deserts, increase in the salt content of soils).

[ ] NUCLEAR POWER STATIONS (nuclear waste management and disposal, cost of construction, safety, sabotage).

[ ] USE AND ABUSE OF TECHNOLOGY (the electronic information explosion, education and the distribution of knowledge, genetic engineering, worldwide communication networks, job creation, indoctrination by television, the rapid sharing of controversial information by satellite).

[ ] IGNORANT DECISION MAKERS (scientifically and technologically illiterate community leaders, science and the humanities as two different cultures).

C) RLGPI (THE REVISED LE GRANGE GLOBAL PRIORITIES INSTRUMENT):

RANKINGS OF ENVIRONMENTAL SCIENCE- AND TECHNOLOGY-RELATED GLOBAL PROBLEMS

What do you see as the most important global problems related to science and technology in your life? Rank the following from 1 to 12 (with 1 indicating your top priority). Insert the numbers in the appropriate brackets.

GLOBAL WORLD PROBLEM

[ ] **POPULATION GROWTH** (Over-population, immigration, living space, Earth's carrying capacity)

[ ] **HAZARDOUS SUBSTANCES** (Waste dumps, toxic chemicals, electromagnetic wave radiation e.g. ultraviolet radiation from the sun)

[ ] **HUMAN HEALTH AND DISEASE** (Contagious and non-contagious diseases such as AIDS & HIV, mental health, stress, exercise, noise, diet and nutrition, malaria, tuberculosis)

[ ] **FRESH WATER SUPPLIES** (Waste disposal, ground water contamination, fertiliser contamination, prediction of droughts and floods, unsafe and unsanitary water sources, water-intensive human activities in agriculture and factories)

[ ] **LOSS OF BIODIVERSITY** (Endangered and extinct animals and plants, pollution and reduction of life in the oceans, desertification, deforestation, wildlife protection)

[ ] **ENERGY NEEDS** (Fossil fuels, solar power, wind power, fewer resources, oil production)

[ ] **WAR TECHNOLOGY** (Terrorism, biological warfare, nuclear weapons threat)

[ ] **AIR POLLUTION** (Methane gas from livestock, acid rain, $CO2$, depletion of Ozone layer, global warming, transportation)

[ ] **WORLD HUNGER AND FOOD RESOURCES** (Food production, food security, crops and agriculture methods such as mono-crop culture, pesticides, herbicides)

[ ] **BAD LAND USE** (Soil erosion, city spread and growth, wild life habitat loss, removal of forests, palm oil plantations, overgrazing leading to desertification)

[ ] **USE AND ABUSE OF TECHNOLOGY** (Uncontrollable artificial intelligence leading to world domination, education and the distribution of knowledge, genetic engineering, indoctrination by television)

[ ] **IGNORANT DECISION MAKERS** (Scientifically and technologically illiterate leaders, science and humanities as two different cultures, corrupt government)

D) THE RLGPI (REVISED LE GRANGE GLOBAL PRIORITIES INSTRUMENT) UPDATED TO PICK-THE-BEST OPTION SCALE AS USED IN THIS STUDY:

UNIVERSITEIT • STELLENBOSCH • UNIVERSITY

This questionnaire forms part of a research study being conducted by an Education Masters student at the University of Stellenbosch on science and technology related global problems and the prioritisation of these problems by Engineering and Education students. This questionnaire will not take longer than 15 minutes to complete. Your participation will be much appreciated.

Section 1

1. Circle your GENDER: Male / Female
2. Circle your FACULTY: Education / Engineering
3. How old are you? __________
4. What year of your course are you in? ___________

Section 2

Description of the terms:

Population growth (over population, immigration, living space, carrying capacity)

Hazardous substances (Waste dumps, toxic chemicals, electromagnetic wave radiation e.g. ultraviolet radiation from the sun)

Human health and disease (Contagious and non-contagious diseases such as AIDS & HIV, mental health, stress, exercise, noise, diet and nutrition, Malaria, Tuberculosis)

Fresh water supplies (Waste disposal, ground water contamination, fertiliser contamination, prediction of droughts and floods, unsafe and unsanitary water sources, water intensive human activities in agriculture and factories)

Loss of biodiversity (Endangered and extinct animals and plants, pollution and reduction of life in the oceans, desertification, deforestation, wildlife protection)

Energy needs (Fossil fuels, solar power, wind power, fewer resources, oil production)

War technology (Terrorism, biological warfare, nuclear weapons threat)

Air pollution (Methane gas from livestock, acid rain, CO_2, depletion of Ozone layer, global warming, transportation)

World hunger and food resources (Food production, food security, crops and agriculture methods such as mono-crop culture, pesticides, herbicides)

Bad land use (Soil erosion, city spread and growth, wild life habitat loss, removal of forests, Palm oil plantations, overgrazing leading to desertification)

Use and abuse of technology (Uncontrollable artificial intelligence leading to world domination, education and the distribution of knowledge, genetic engineering, indoctrination by Television)

Ignorant decision makers (Scientifically and technologically illiterate leaders, science and humanities as two different cultures, corrupt government)

In the following section of questions, please select the priority you consider to be **MOST** important as well as the priority you consider to be **LEAST** important when thinking about your personal life and influences by your course, social media and the news.

Check **ONLY ONE** priority for each of the most and least columns in each table.

Each table will thus have one priority ticked for each of the **MOST** and **LEAST** columns.

Example:

Least	Priority	Most
	Bad land use	
X	War technology	
	Population Growth	X
	Use and abuse of technology	

Least	Priority	Most
	Air pollution	
	War technology	
	Population growth	
	Use and abuse of technology	

Least	Priority	Most
	Use and abuse of technology	
	Bad land use	
	Fresh water supplies	
	Hazardous substances	

Least	Priority	Most
	Ignorant decision makers	
	Use and abuse of technology	
	Loss of biodiversity	
	Human health and disease	

Least	Priority	Most
	Hazardous substances	
	Population growth	
	War technology	
	Loss of biodiversity	

Least	Priority	Most
	War technology	
	Energy needs	
	Ignorant decision makers	
	Bad land use	

Least	Priority	Most
	World hunger and food resources	
	Air pollution	
	Hazardous substances	
	Ignorant decision makers	

Least	Priority	Most
	Loss of biodiversity	
	Fresh water supplies	
	Bad land use	
	Air pollution	

Least	Priority	Most
	Fresh water supplies	
	Human health and disease	
	World hunger and food resources	
	War technology	

Least	Priority	Most
	Population growth	
	Ignorant decision makers	
	Energy needs	
	Fresh water supplies	

Least	Priority	Most
	Human health and disease	
	Hazardous substances	
	Air pollution	
	Energy needs	

Least	Priority	Most
	Energy needs	
	Loss of biodiversity	
	Use and abuse of technology	
	World hunger and food resources	

Least	Priority	Most
	Bad land use	
	World hunger and food resources	
	Human health and disease	
	Population growth	

E) INSTITUTIONAL PERMISSION FOR RESEARCH:

UNIVERSITEIT • STELLENBOSCH • UNIVERSITY jou kennisvennoot • your knowledge partner

04 December 2015

Ms Jadri Barnard
Department of Curriculum Studies
Stellenbosch University

Dear Ms Barnard

Research project: ***Stellenbosch University Engineering and Education students' rankings of science and technology related global problems***

Institutional permission is granted for soliciting the participation of Stellenbosch University (SU) students for the purpose of this study as stipulated in the institutional permission. This permission is granted on the following conditions:

- Participation is voluntary.
- Persons may not be coerced into participation.
- Persons who choose to participate must be informed of the purpose of the research, all the aspects of their participation, the risks to participation, their role in the research and their rights as participants. Participants must consent to participation. The researcher may not proceed until she is confident that all the before mentioned has been established and recorded.
- Persons who choose not to participate may not be penalized as a result of non-participation.
- Participants may withdraw their participation at any time, and without consequence.
- Data must be collected and processed in a way that ensures the anonymity of all participants.
- The data that is collected must be responsibly and suitably protected.
- The researcher must pay due diligence in seeing that the data is handled in the strictest confidence.
- The use of the collected data may not be extended beyond the purpose of this study.
- Individuals may not be identified in the report(s) or publication(s) of the results of the study.
- The privacy of individuals must be respected and protected.
- The researcher must conduct her research within the provisions of the Protection of Personal Information Act, 2013.

Best wishes,

I. Cloete.

Prof Ian Cloete

Senior Director: Institutional Research and Planning

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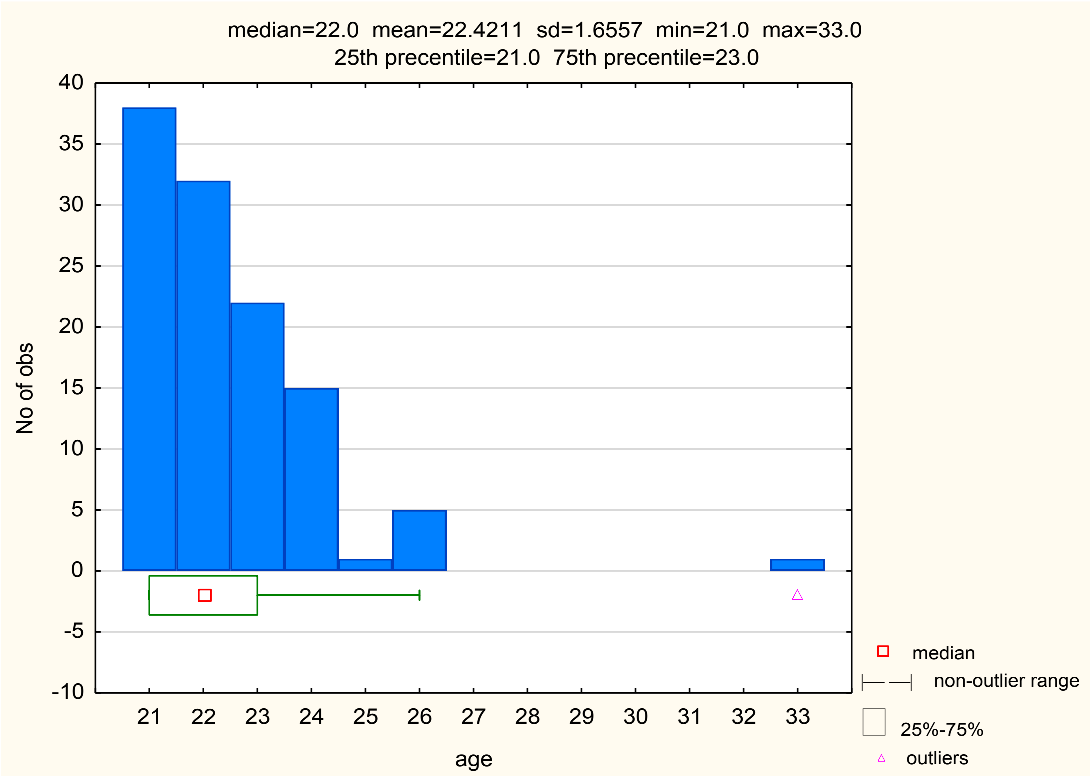
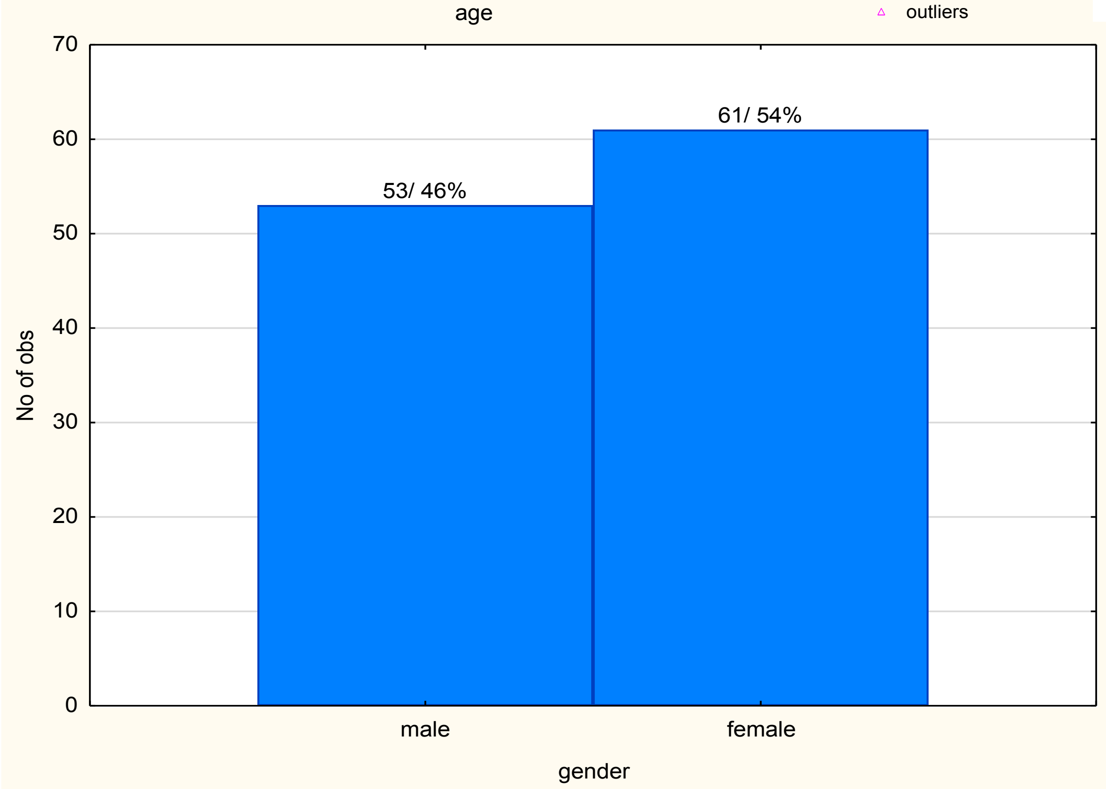
2D HISTOGRAMS

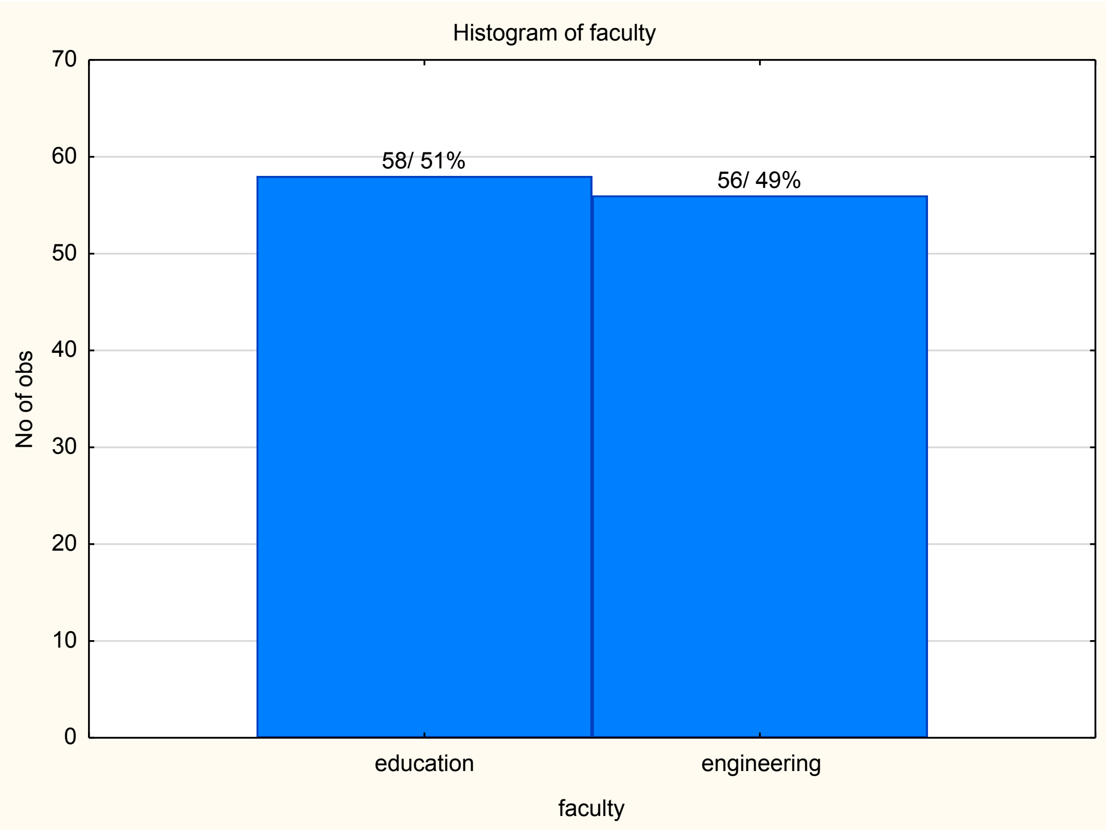
F) NUMBER OF REPONDENTS ACCORING TO AGE





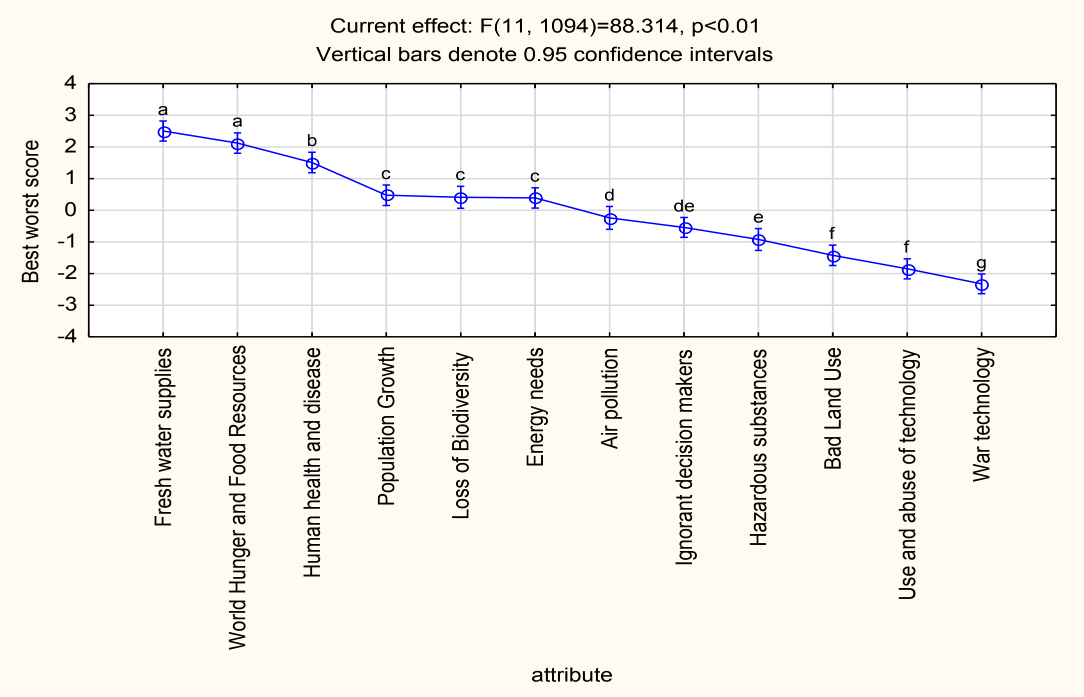
G) NUMBER OF RESPONDENTS ACCORDING TO GENDER

H) NUMBER OF RESPONDENTS ACORDING TO FACULTY



ALL RESPONDENTS

I) BEST WORST SCORE OF ALL REPONDENTS



ATTRIBUTE; LS MEANS

J) LSD TEST; VARIABLE SCORE (ATTRIBUTE SCORES OF ALL RESPONDENTS)

Comparisons Cell {#1}-{#2}	LSD test; variable score (attribute scores in resultate.stw) Simultaneous confidence intervals Effect: attribute				
	1st Mean	2nd Mean	Mean Differ.	Standard Error	p
{1}-{2}	Air pollution	Bad Land Use	1.18	0.25	0.00
{1}-{3}	Air pollution	Fresh water supplies	-2.75	0.25	0.00
{1}-{4}	Air pollution	Use and abuse of technology	1.61	0.25	0.00
{1}-{5}	Air pollution	Human health and disease	-1.75	0.25	0.00
{1}-{6}	Air pollution	Population Growth	-0.72	0.25	0.00
{1}-{7}	Air pollution	War technology	2.08	0.24	0.00
{1}-{8}	Air pollution	Energy needs	-0.63	0.25	0.01
{1}-{9}	Air pollution	Ignorant decision makers	0.30	0.24	0.22

{1}-{10}	Air pollution	World Hunger and Food Resources	-2.36	0.25	0.00
{1}-{11}	Air pollution	Hazardous substances	0.68	0.25	0.01
{1}-{12}	Air pollution	Loss of Biodiversity	-0.65	0.25	0.01
{2}-{3}	Bad Land Use	Fresh water supplies	-3.93	0.23	0.00
{2}-{4}	Bad Land Use	Use and abuse of technology	0.43	0.23	0.06
{2}-{5}	Bad Land Use	Human health and disease	-2.93	0.23	0.00
{2}-{6}	Bad Land Use	Population Growth	-1.90	0.23	0.00
{2}-{7}	Bad Land Use	War technology	0.90	0.23	0.00
{2}-{8}	Bad Land Use	Energy needs	-1.81	0.23	0.00
{2}-{9}	Bad Land Use	Ignorant decision makers	-0.88	0.23	0.00
{2}-{10}	Bad Land Use	World Hunger and Food Resources	-3.55	0.23	0.00
{2}-{11}	Bad Land Use	Hazardous substances	-0.50	0.24	0.04
{2}-{12}	Bad Land Use	Loss of Biodiversity	-1.83	0.24	0.00
{3}-{4}	Fresh water supplies	Use and abuse of technology	4.36	0.23	0.00
{3}-{5}	Fresh water supplies	Human health and disease	1.00	0.23	0.00
{3}-{6}	Fresh water supplies	Population Growth	2.03	0.23	0.00
{3}-{7}	Fresh water supplies	War technology	4.83	0.23	0.00
{3}-{8}	Fresh water supplies	Energy needs	2.11	0.23	0.00
{3}-{9}	Fresh water supplies	Ignorant decision makers	3.05	0.23	0.00
{3}-{10}	Fresh water supplies	World Hunger and Food Resources	0.38	0.23	0.10
{3}-{11}	Fresh water supplies	Hazardous substances	3.43	0.24	0.00
{3}-{12}	Fresh water supplies	Loss of Biodiversity	2.09	0.24	0.00
{4}-{5}	Use and abuse of technology	Human health and disease	-3.36	0.23	0.00
{4}-{6}	Use and abuse of technology	Population Growth	-2.33	0.23	0.00
{4}-{7}	Use and abuse of technology	War technology	0.47	0.23	0.04
{4}-{8}	Use and abuse of technology	Energy needs	-2.24	0.23	0.00
{4}-{9}	Use and abuse of technology	Ignorant decision makers	-1.31	0.23	0.00

{4}-{10}	Use and abuse of technology	World Hunger and Food Resources	-3.97	0.23	0.00
{4}-{11}	Use and abuse of technology	Hazardous substances	-0.93	0.24	0.00
{4}-{12}	Use and abuse of technology	Loss of Biodiversity	-2.26	0.24	0.00
{5}-{6}	Human health and disease	Population Growth	1.03	0.23	0.00
{5}-{7}	Human health and disease	War technology	3.83	0.23	0.00
{5}-{8}	Human health and disease	Energy needs	1.12	0.23	0.00
{5}-{9}	Human health and disease	Ignorant decision makers	2.05	0.23	0.00
{5}-{10}	Human health and disease	World Hunger and Food Resources	-0.61	0.23	0.01
{5}-{11}	Human health and disease	Hazardous substances	2.43	0.24	0.00
{5}-{12}	Human health and disease	Loss of Biodiversity	1.10	0.24	0.00
{6}-{7}	Population Growth	War technology	2.80	0.23	0.00
{6}-{8}	Population Growth	Energy needs	0.09	0.23	0.71
{6}-{9}	Population Growth	Ignorant decision makers	1.02	0.23	0.00
{6}-{10}	Population Growth	World Hunger and Food Resources	-1.65	0.23	0.00
{6}-{11}	Population Growth	Hazardous substances	1.40	0.24	0.00
{6}-{12}	Population Growth	Loss of Biodiversity	0.06	0.24	0.79
{7}-{8}	War technology	Energy needs	-2.71	0.23	0.00
{7}-{9}	War technology	Ignorant decision makers	-1.78	0.23	0.00
{7}-{10}	War technology	World Hunger and Food Resources	-4.45	0.23	0.00
{7}-{11}	War technology	Hazardous substances	-1.40	0.24	0.00
{7}-{12}	War technology	Loss of Biodiversity	-2.74	0.24	0.00
{8}-{9}	Energy needs	Ignorant decision makers	0.93	0.23	0.00
{8}-{10}	Energy needs	World Hunger and Food Resources	-1.73	0.23	0.00
{8}-{11}	Energy needs	Hazardous substances	1.31	0.24	0.00
{8}-{12}	Energy needs	Loss of Biodiversity	-0.02	0.24	0.93
{9}-{10}	Ignorant decision makers	World Hunger and Food Resources	-2.67	0.23	0.00
{9}-{11}	Ignorant decision makers	Hazardous substances	0.38	0.24	0.11

{9}-{12}	Ignorant decision makers	Loss of Biodiversity	-0.95	0.24	0.00
{10}-{11}	World Hunger and Food Resources	Hazardous substances	3.05	0.24	0.00
{10}-{12}	World Hunger and Food Resources	Loss of Biodiversity	1.71	0.24	0.00
{11}-{12}	Hazardous substances	Loss of Biodiversity	-1.33	0.25	0.00

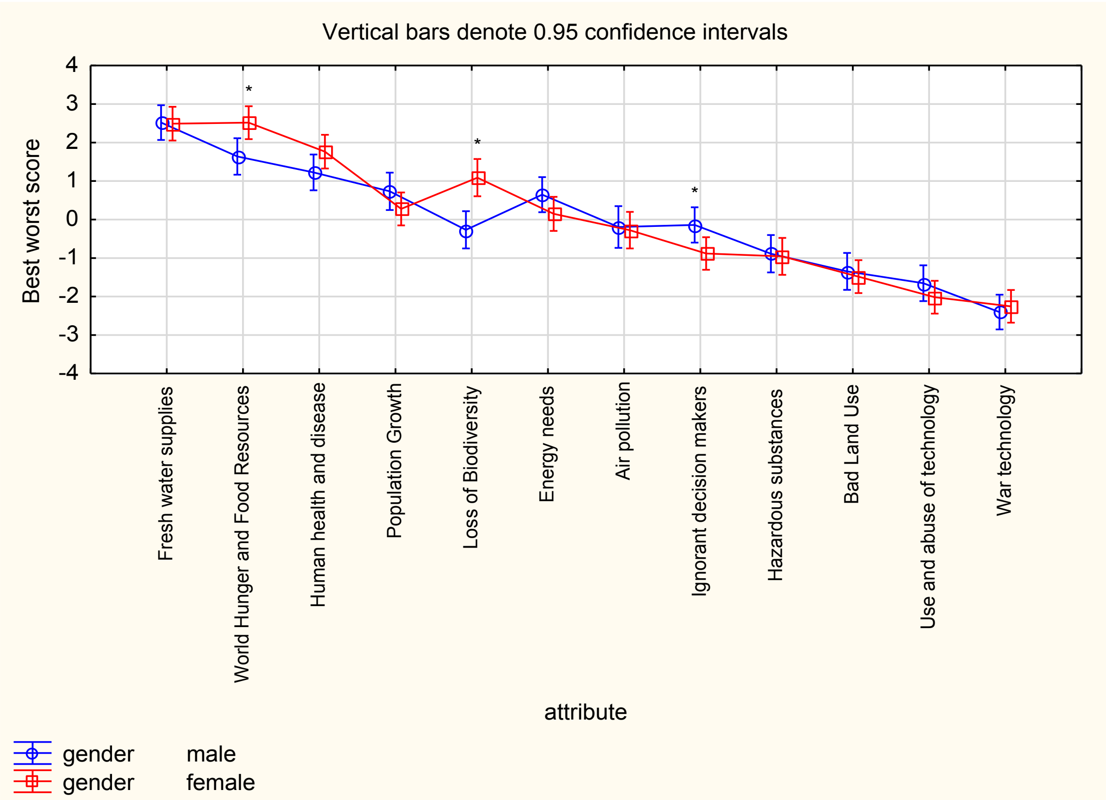
DESCRIPTIVE STATISTICS BY GENDER

K) DESCRIPTIVE STATISTICS INDICATING DIFFERENCES IN GENDER RANKINGS

Effect	Descriptive Statistics (attribute scores in resultate.stw) Level of Factor	N	score Mean	score Std.Dev.
attribute	Air pollution	83	-0.24	1.78
attribute	Bad Land Use	104	-1.42	1.44
attribute	Fresh water supplies	107	2.50	1.16
attribute	Use and abuse of technology	107	-1.85	1.73
attribute	Human health and disease	104	1.51	1.48
attribute	Population Growth	103	0.48	2.00
attribute	War technology	111	-2.32	1.63
attribute	Energy needs	105	0.39	1.51
attribute	Ignorant decision makers	109	-0.54	2.08
attribute	World Hunger and Food Resources	105	2.12	1.43
attribute	Hazardous substances	91	-0.92	1.48
attribute	Loss of Biodiversity	90	0.41	2.17

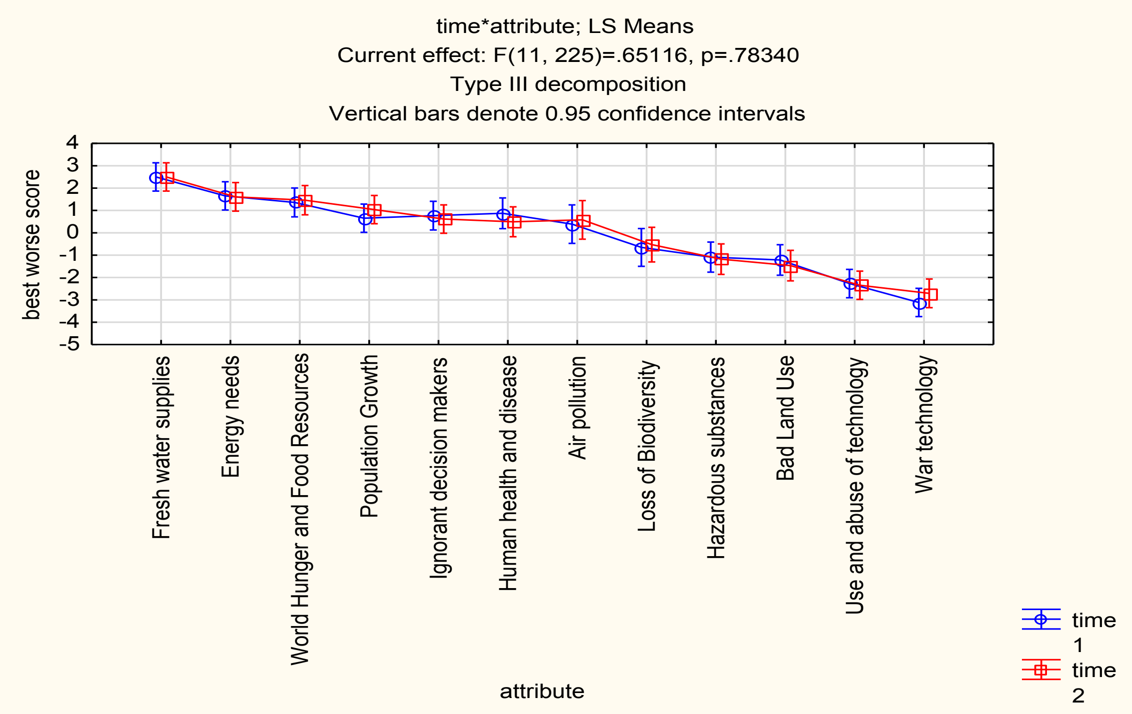
L) LINE GRAPH INDICATING DIFERENCES IN GENDER RANKINGS

GENDER ATTRIBUTE; LS MEANS



M) VARIANCE ESTIMATION, PRECISION & COMPARISON (VEPAC) (BREAKDOWN TABLE OF DESCRIPTIVE STATISTICS)

BEST WORSE SCORE OF TIME*ATTRIBUTE; LS MEANS



N) LSD TABLE OF PILOT STUDY TIME 1 VS TIME 2

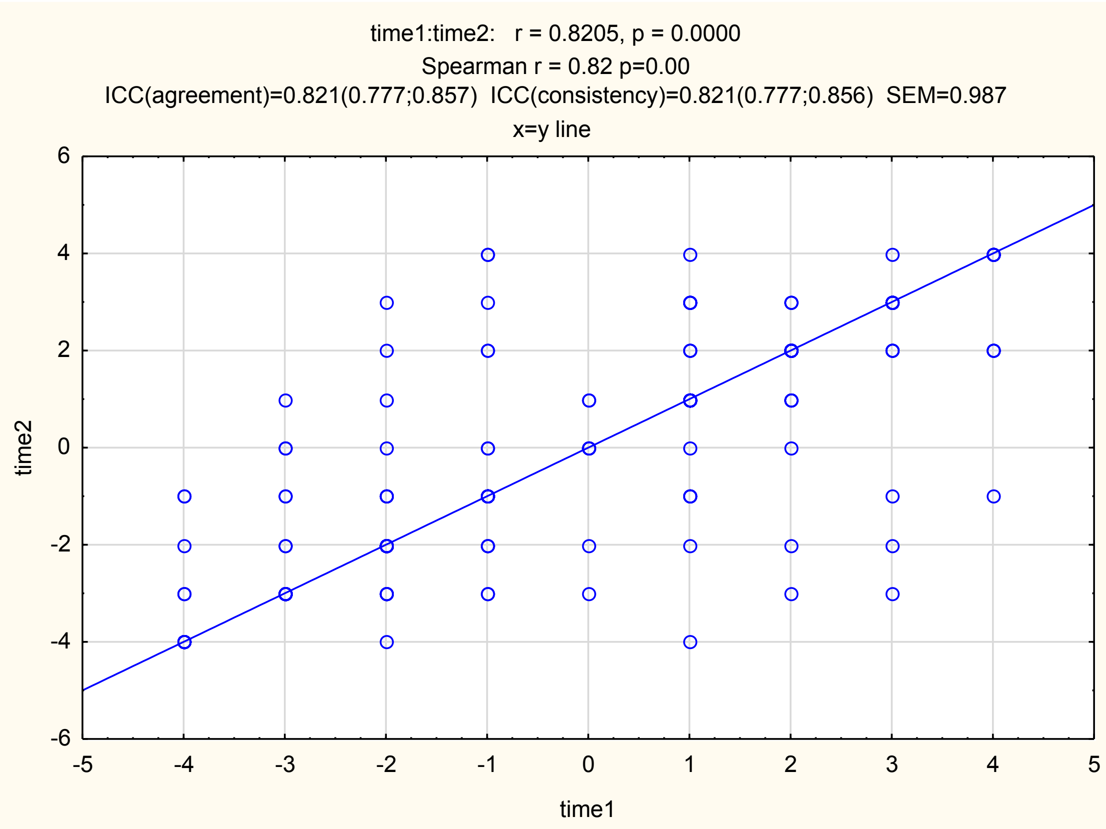
	1 attribute	2 time1	3 time2	4 p
1	Fresh water supplies	1	2	1.00
2	Energy needs	1	2	0.87
3	World Hunger and Food Resources	1	2	0.73
4	Population Growth	1	2	0.16
5	Ignorant decision makers	1	2	0.58
6	Human health and disease	1	2	0.22
7	Air pollution	1	2	0.65
8	Loss of Biodiversity	1	2	0.75
9	Hazardous substances	1	2	0.76
10	Bad Land Use	1	2	0.41
11	Use and abuse of technology	1	2	0.78
12	War technology	1	2	0.15

O) DESCRIPTIVE STATISTICS (BREAKDOWN TABLE OF DESCRIPTIVE STATISTICS)

Effect	Descriptive Statistics (Breakdown Table of Descriptive Statistics (Spreadsheet8) in resultate.stw) Level of Factor	Level of Factor	N	best worse score Mean	best worse score Std.Dev.
time*attribute	1	Fresh water supplies	26	2.50	1.21
time*attribute	1	Energy needs	26	1.65	1.32
time*attribute	1	World Hunger and Food Resources	25	1.36	1.89
time*attribute	1	Population Growth	26	0.65	1.60
time*attribute	1	Ignorant decision makers	25	0.76	2.39
time*attribute	1	Human health and disease	21	0.86	1.20
time*attribute	1	Air pollution	13	0.23	1.96
time*attribute	1	Loss of Biodiversity	13	-0.54	1.81
time*attribute	1	Hazardous substances	23	-1.09	1.68
time*attribute	1	Bad Land Use	22	-1.23	1.41
time*attribute	1	Use and abuse of technology	26	-2.27	1.54
time*attribute	1	War technology	26	-3.12	1.24
time*attribute	2	Fresh water supplies	26	2.50	1.30
time*attribute	2	Energy needs	25	1.60	1.12
time*attribute	2	World Hunger and Food Resources	24	1.42	1.79
time*attribute	2	Population Growth	26	1.04	1.61
time*attribute	2	Ignorant decision makers	26	0.62	2.64
time*attribute	2	Human health and disease	23	0.43	1.31
time*attribute	2	Air pollution	13	0.54	2.07
time*attribute	2	Loss of Biodiversity	17	-0.59	1.87
time*attribute	2	Hazardous substances	22	-1.18	1.50
time*attribute	2	Bad Land Use	22	-1.50	1.60
time*attribute	2	Use and abuse of technology	26	-2.35	1.35
time*attribute	2	War technology	25	-2.76	1.36

P) 2D SCATTERPLOTS:

TIME1 VS TIME2



Q) LSD TEST; VARIABLE SCORE (ATTRIBUTE SCORES)

LSD test; variable score (attribute scores in resultate.stw)
Simultaneous confidence intervals
Effect: gender*attribute

Comparisons Cell {#1}-{#2}	1st Mean	2nd Mean	Mean Differ.	Standard Error	p
{1}-{13}	male*Fresh water supplies	female*Fresh water supplies	0.03	0.32	0.93
{2}-{14}	male*World Hunger and Food Resources	female*World Hunger and Food Resources	-0.88	0.33	0.01
{3}-{15}	male*Human health and disease	female*Human health and disease	-0.54	0.33	0.10
{4}-{16}	male*Population Growth	female*Population Growth	0.46	0.33	0.17
{5}-{17}	male*Loss of Biodiversity	female*Loss of Biodiversity	-1.36	0.35	0.00
{6}-{18}	male*Energy needs	female*Energy needs	0.50	0.32	0.12
{7}-{19}	male*Air pollution	female*Air pollution	0.08	0.37	0.82
{8}-{20}	male*Ignorant decision makers	female*Ignorant decision makers	0.74	0.32	0.02
{9}-{21}	male*Hazardous substances	female*Hazardous substances	0.07	0.35	0.85
{10}-{22}	male*Bad Land Use	female*Bad Land Use	0.13	0.33	0.68
{11}-{23}	male*Use and abuse of technology	female*Use and abuse of technology	0.36	0.32	0.26
{12}-{24}	male*War technology	female*War technology	-0.15	0.32	0.64

R) DESCRIPTIVE STATISTICS (ATTRIBUTE SCORES)

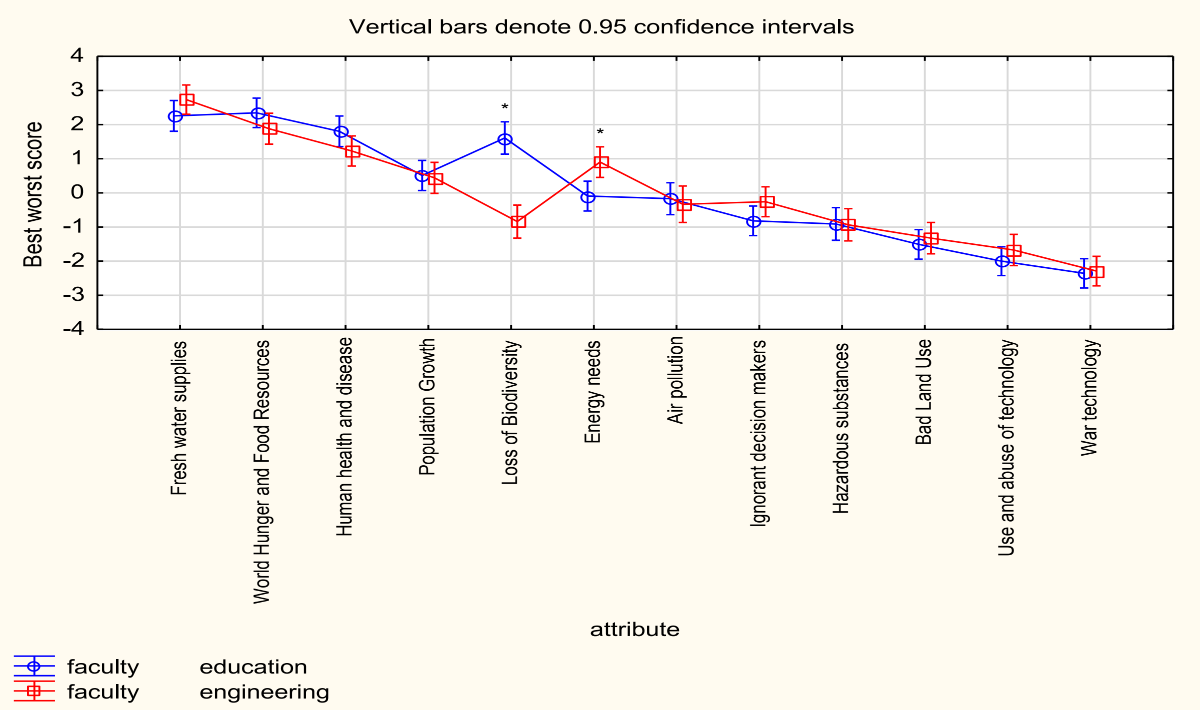
Descriptive Statistics (attribute scores in resultate.stw)

Effect	Level of Factor	Level of Factor	N	score Mean	score Std.Dev.
gender*attribute	male	Fresh water supplies	52	2.52	1.06
gender*attribute	male	World Hunger and Food Resources	47	1.64	1.67
gender*attribute	male	Human health and disease	49	1.22	1.52
gender*attribute	male	Population Growth	45	0.73	2.22
gender*attribute	male	Loss of Biodiversity	45	-0.27	2.31
gender*attribute	male	Energy needs	51	0.65	1.45
gender*attribute	male	Air pollution	36	-0.19	1.74
gender*attribute	male	Ignorant decision makers	50	-0.14	1.95
gender*attribute	male	Hazardous substances	45	-0.89	1.37
gender*attribute	male	Bad Land Use	46	-1.35	1.65
gender*attribute	male	Use and abuse of technology	49	-1.65	1.64
gender*attribute	male	War technology	52	-2.40	1.65
gender*attribute	female	Fresh water supplies	55	2.49	1.26
gender*attribute	female	World Hunger and Food Resources	58	2.52	1.05
gender*attribute	female	Human health and disease	55	1.76	1.41
gender*attribute	female	Population Growth	58	0.28	1.80
gender*attribute	female	Loss of Biodiversity	45	1.09	1.79
gender*attribute	female	Energy needs	54	0.15	1.53
gender*attribute	female	Air pollution	47	-0.28	1.84
gender*attribute	female	Ignorant decision makers	59	-0.88	2.13
gender*attribute	female	Hazardous substances	46	-0.96	1.60
gender*attribute	female	Bad Land Use	58	-1.48	1.26
gender*attribute	female	Use and abuse of technology	58	-2.02	1.79
gender*attribute	female	War technology	59	-2.25	1.63

BY FACULTY

S) SCORE OF ENGINEERING STUDENTS VS EDUCATION STUDENTS

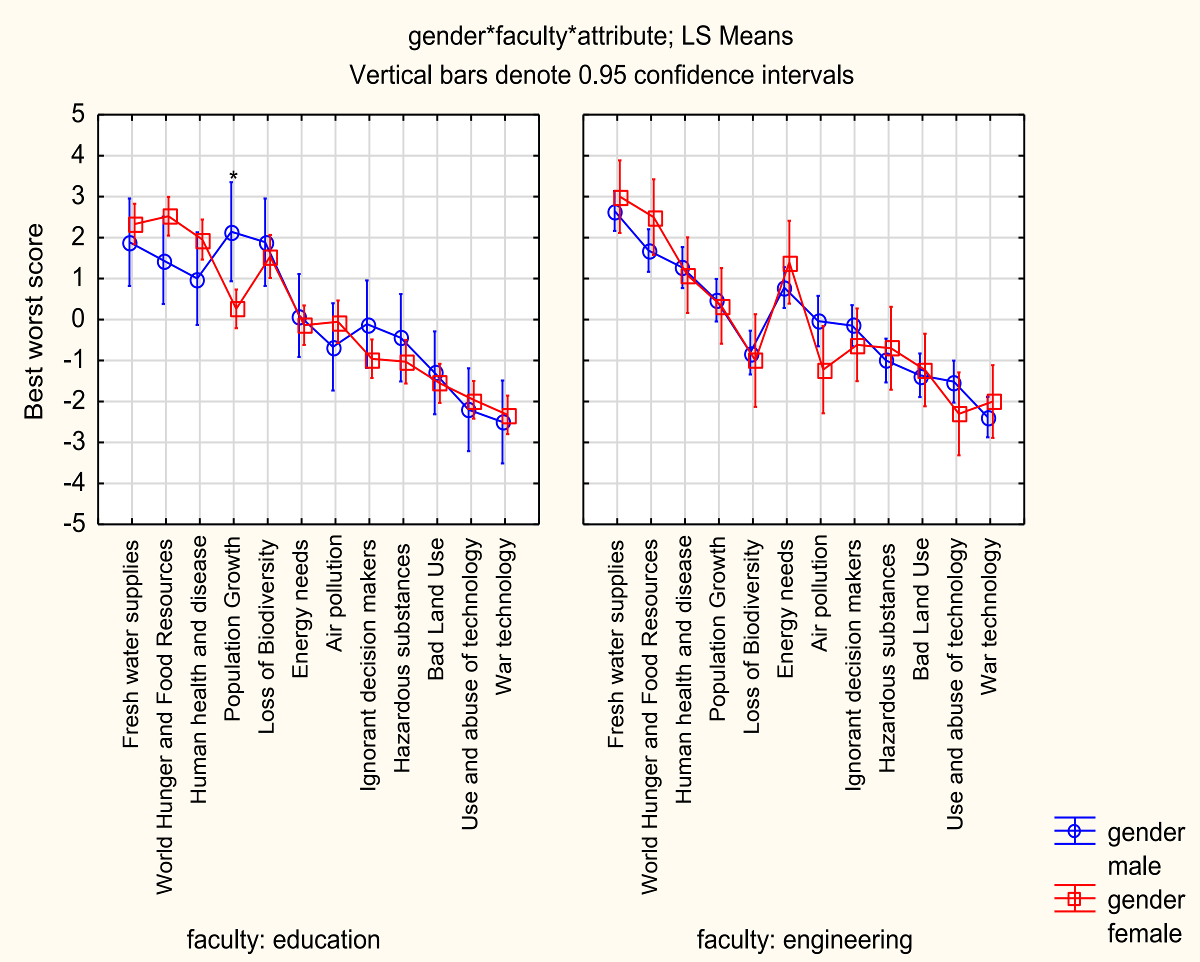
ATTRIBUTE*FACULTY; LS MEANS

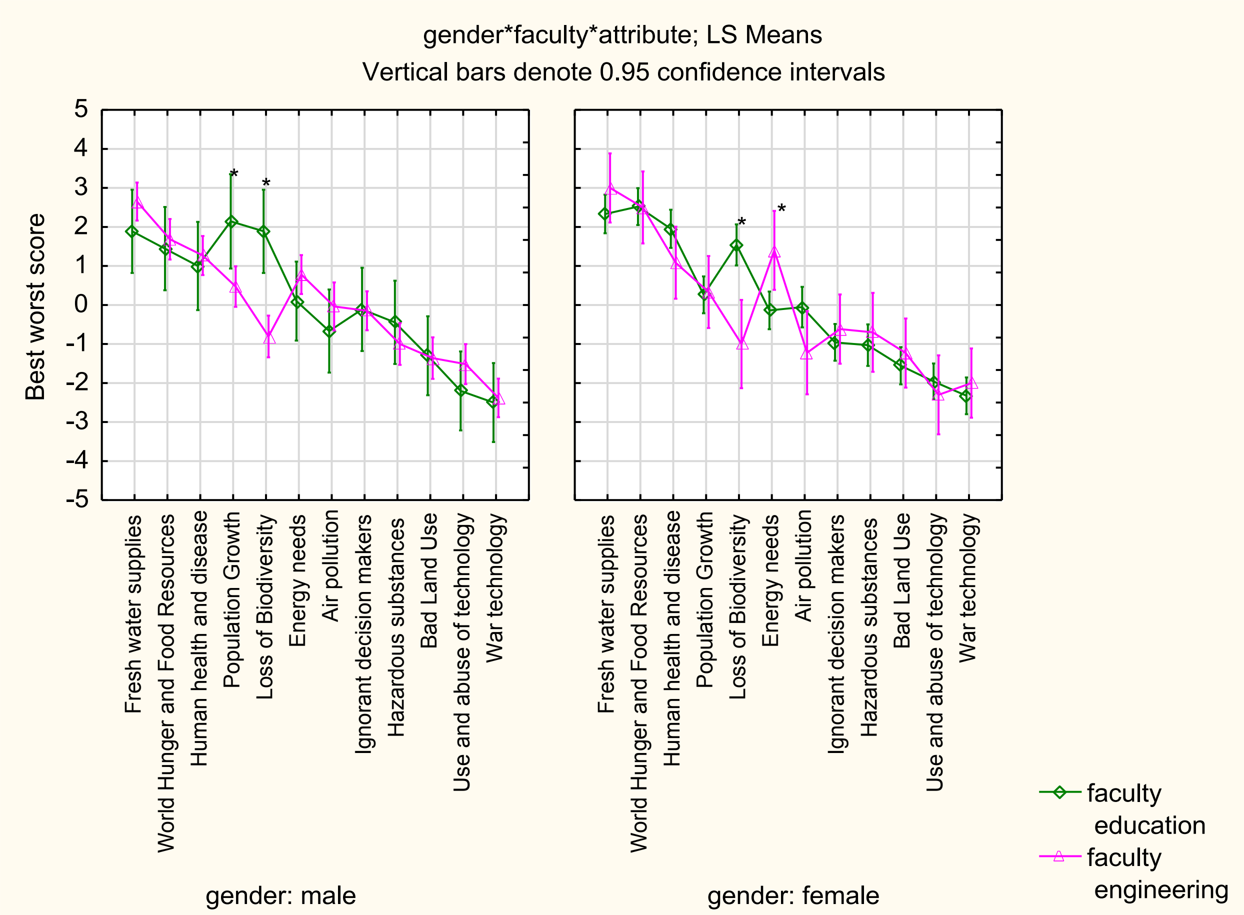


T) LSD TEST; VARIABLE SCORE (ENGINEERING STUDENTS VS. EDUCATION STUDENTS)

Comparisons Cell {#1}-{#2}	LSD test; variable score (attribute scores in resultate.stw) Simultaneous confidence intervals Effect: attribute*faculty 1st Mean	2nd Mean	Mean Differ.	Standard Error	p
{1}-{2}	Fresh water supplies*education	Fresh water supplies*engineering	-0.48	0.32	0.13
{3}-{4}	World Hunger and Food Resources*education	World Hunger and Food Resources*engineering	0.47	0.32	0.15
{5}-{6}	Human health and disease*education	Human health and disease*engineering	0.58	0.32	0.07
{7}-{8}	Population Growth*education	Population Growth*engineering	0.07	0.32	0.83
{9}-{10}	Loss of Biodiversity*education	Loss of Biodiversity*engineering	2.45	0.34	0.00
{11}-{12}	Energy needs*education	Energy needs*engineering	-0.99	0.32	0.00
{13}-{14}	Air pollution*education	Air pollution*engineering	0.16	0.36	0.65
{15}-{16}	Ignorant decision makers*education	Ignorant decision makers*engineering	-0.56	0.31	0.07
{17}-{18}	Hazardous substances*education	Hazardous substances*engineering	0.02	0.34	0.94
{19}-{20}	Bad Land Use*education	Bad Land Use*engineering	-0.18	0.32	0.57
{21}-{22}	Use and abuse of technology*education	Use and abuse of technology*engineering	-0.33	0.32	0.30
{23}-{24}	War technology*education	War technology*engineering	-0.07	0.31	0.83

U) GENDER*FACULTY*ATTRIBUTE; LS MEANS





V) DESCRIPTIVE STATISTICS GENDER FACULTY ATTRIBUTE

Effect	Descriptive Statistics (attribute scores in resultate.stw)					
	Level of Factor	Level of Factor	Level of Factor	N	score Mean	score Std.Dev.
gender*faculty*attribute	male	education	Fresh water supplies	9	1.89	1.27
gender*faculty*attribute	male	education	World Hunger and Food Resources	9	1.44	1.94
gender*faculty*attribute	male	education	Human health and disease	8	1.00	0.93
gender*faculty*attribute	male	education	Population Growth	7	2.14	1.77
gender*faculty*attribute	male	education	Loss of Biodiversity	9	1.89	1.17
gender*faculty*attribute	male	education	Energy needs	10	0.10	1.60
gender*faculty*attribute	male	education	Air pollution	9	-0.67	2.35
gender*faculty*attribute	male	education	Ignorant decision makers	9	-0.11	1.17
gender*faculty*attribute	male	education	Hazardous substances	9	-0.44	1.51
gender*faculty*attribute	male	education	Bad Land Use	10	-1.30	1.83
gender*faculty*attribute	male	education	Use and abuse of technology	10	-2.20	1.23
gender*faculty*attribute	male	education	War technology	10	-2.50	1.51
gender*faculty*attribute	male	engineering	Fresh water supplies	43	2.65	0.97
gender*faculty*attribute	male	engineering	World Hunger and Food Resources	38	1.68	1.63

gender*faculty*attribute	male	engineering	Human health and disease	41	1.27	1.61
gender*faculty*attribute	male	engineering	Population Growth	38	0.47	2.21
gender*faculty*attribute	male	engineering	Loss of Biodiversity	36	-0.81	2.21
gender*faculty*attribute	male	engineering	Energy needs	41	0.78	1.41
gender*faculty*attribute	male	engineering	Air pollution	27	-0.04	1.51
gender*faculty*attribute	male	engineering	Ignorant decision makers	41	-0.15	2.09
gender*faculty*attribute	male	engineering	Hazardous substances	36	-1.00	1.33
gender*faculty*attribute	male	engineering	Bad Land Use	36	-1.36	1.62
gender*faculty*attribute	male	engineering	Use and abuse of technology	39	-1.51	1.71
gender*faculty*attribute	male	engineering	War technology	42	-2.38	1.70
gender*faculty*attribute	female	education	Fresh water supplies	42	2.33	1.30
gender*faculty*attribute	female	education	World Hunger and Food Resources	46	2.52	1.05
gender*faculty*attribute	female	education	Human health and disease	43	1.95	1.41
gender*faculty*attribute	female	education	Population Growth	46	0.26	1.73
gender*faculty*attribute	female	education	Loss of Biodiversity	37	1.54	1.37
gender*faculty*attribute	female	education	Energy needs	44	-0.14	1.39
gender*faculty*attribute	female	education	Air pollution	38	-0.05	1.74
gender*faculty*attribute	female	education	Ignorant decision makers	46	-0.96	2.09
gender*faculty*attribute	female	education	Hazardous substances	36	-1.03	1.61
gender*faculty*attribute	female	education	Bad Land Use	45	-1.56	1.06
gender*faculty*attribute	female	education	Use and abuse of technology	48	-1.96	1.88
gender*faculty*attribute	female	education	War technology	46	-2.33	1.46
gender*faculty*attribute	female	engineering	Fresh water supplies	13	3.00	1.00
gender*faculty*attribute	female	engineering	World Hunger and Food Resources	12	2.50	1.09
gender*faculty*attribute	female	engineering	Human health and disease	12	1.08	1.24
gender*faculty*attribute	female	engineering	Population Growth	12	0.33	2.15
gender*faculty*attribute	female	engineering	Loss of Biodiversity	8	-1.00	2.14
gender*faculty*attribute	female	engineering	Energy needs	10	1.40	1.58
gender*faculty*attribute	female	engineering	Air pollution	9	-1.22	2.05
gender*faculty*attribute	female	engineering	Ignorant decision makers	13	-0.62	2.36
gender*faculty*attribute	female	engineering	Hazardous substances	10	-0.70	1.64
gender*faculty*attribute	female	engineering	Bad Land Use	13	-1.23	1.83
gender*faculty*attribute	female	engineering	Use and abuse of technology	10	-2.30	1.34
gender*faculty*attribute	female	engineering	War technology	13	-2.00	2.16

W) DESCRIPTIVE STATISTICS OF ENGINEERING STUDENTS VS. EDUCATION STUDENTS SCORES

Effect	Descriptive Statistics (attribute scores in resultate.stw) Level of Factor	Level of Factor	N	score Mean	score Std.Dev.
attribute*faculty	Fresh water supplies	education	51	2.25	1.29
attribute*faculty	Fresh water supplies	engineering	56	2.73	0.98
attribute*faculty	World Hunger and Food Resources	education	55	2.35	1.28
attribute*faculty	World Hunger and Food Resources	engineering	50	1.88	1.55
attribute*faculty	Human health and disease	education	51	1.80	1.39
attribute*faculty	Human health and disease	engineering	53	1.23	1.53
attribute*faculty	Population Growth	education	53	0.51	1.84
attribute*faculty	Population Growth	engineering	50	0.44	2.18
attribute*faculty	Loss of Biodiversity	education	46	1.61	1.32
attribute*faculty	Loss of Biodiversity	engineering	44	-0.84	2.18
attribute*faculty	Energy needs	education	54	-0.09	1.42
attribute*faculty	Energy needs	engineering	51	0.90	1.45
attribute*faculty	Air pollution	education	47	-0.17	1.86
attribute*faculty	Air pollution	engineering	36	-0.33	1.71
attribute*faculty	Ignorant decision makers	education	55	-0.82	1.98
attribute*faculty	Ignorant decision makers	engineering	54	-0.26	2.15
attribute*faculty	Hazardous substances	education	45	-0.91	1.59
attribute*faculty	Hazardous substances	engineering	46	-0.93	1.39
attribute*faculty	Bad Land Use	education	55	-1.51	1.22
attribute*faculty	Bad Land Use	engineering	49	-1.33	1.66
attribute*faculty	Use and abuse of technology	education	58	-2.00	1.78
attribute*faculty	Use and abuse of technology	engineering	49	-1.67	1.66
attribute*faculty	War technology	education	56	-2.36	1.46
attribute*faculty	War technology	engineering	55	-2.29	1.80