# EXPLORING ENGINEERING STUDENTS' EPISTEMIC BELIEFS AND MOTIVATION: A CASE OF A SOUTH AFRICAN UNIVERSITY

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### ABSTRACT

This study seeks to investigate how chemical engineering students from South African low-income communities locate knowledge structures. The study used an existing Engineering Related Beliefs Questionnaire (ERBQ) to evaluate beliefs of 268 chemical engineering students. The questionnaire collects additional information by allowing open-ended responses on each item to increase reliability of the questionnaire. Findings suggest that more than 60 per cent of students believe that engineering knowledge cannot be argued, and that learning takes place only when the lecturer transmits knowledge. Engineering educators may consider a humanizing pedagogy, which create opportunities for students from low-income communities to be liberated and reduce the dependency culture. Application of this pedagogy may assist students to achieve life long learning whilst developing necessary soft skills like independent thinking and innovation. **Keywords:** epistemic beliefs, African students, engineering

# INTRODUCTION

In recent years, investigation of epistemic beliefs has received increasing attention among educational scholars. Epistemology can be best described as "beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides and how knowing occurs" (Hofer 2002, 4). These beliefs have an impact on how people use knowledge and consequently have a crucial influence on students' thinking and learning (Schommer 1990; Hofer 2001; Greene, Muis and Pieschl 2010). The specifics and peculiarities of these beliefs cascade back upon the success or performance of the students as output of their learning process.

Most studies on epistemic beliefs begin with Perry and Chickering's (1997) analysis of the relationship between epistemic beliefs and their impacts in university students. Perry may be regarded as the originator of epistemic development scholarship in higher education (Muis 2007). In engineering, Pavelich and Moore (1996) used Perry's epistemic development constructs to measure undergraduate students' knowledge insights and found major variances in assessments among first-year and senior students. Elsewhere, Wise, Lee, Litzinger and Palmer (2004) found that level of study had a decisive influence on engineering students' Perry assessments, with wide variance between first-year students and final-year students. In a study by Marra, Palmer and Litzinger (2000) level of study was excluded and the focus instead was on the impact of an entry-level design module on engineering students' epistemic beliefs, and in a subsequent study Marra and Palmer (2004) established that engineering students' Perry assessments were interrelated to engagement of engineering design principles when disentangling complex problems.

This study recognizes the AIR model of epistemic cognition, recently proposed as a robust framework by Chinn, Rinehart and Buckland (2014), which seeks to merge educational psychology and research in philosophy. Epistemic cognition denotes multifaceted cognitions interlinked with the accomplishment of epistemic ends, including suitable models, explanations and knowledge (Chinn et al. 2014). Chinn and colleagues expanded the constructs, based on psychological and philosophical deliberations, which extended work done by Hofer and Pintrich (1997). Hofer and Pintrich separated constructs into epistemic aims, the structure of epistemic accomplishment, and rationalization of epistemic position, epistemic virtue (motivation) and process for achieving epistemic aims. From these constructs, this study picked epistemic motivation that impacts acquisition of epistemic aims differentiated into two groups: epistemic virtue and epistemic vice. Subsequently, this study used the suggestion by Webster and Kruglanski (1994) that epistemic beliefs are similar to epistemic motivations since they both influence features of learning and social psychological occurrences. Kruglanski (1990) made a distinction between epistemic virtues, being characteristics that assist in acquisition of knowledge and understanding, and epistemic vices, being characteristics that hinder acquisition of knowledge and understanding. Chinn, Buckland and Samarapungavan (2011) identify distress with obscurity and close-mindedness as epistemic devices. Kruglanski (1990) measured epistemic motivation by identifying two consequences of cognitive closure - "seizing" and "freezing" – using the Need for Cognitive Closure Scale.

Epistemic beliefs of students in higher education have been explored using both quantitative and qualitative research approaches. An observable trend has been studies where each of the research approaches gives valuable conclusions showing that epistemic beliefs

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become increasingly cultured as students progress to higher levels of study (Schommer 1993; Wise et al. 2004). Although quantitative studies using the epistemic belief questionnaire have been criticized by DeBacker, Crowson, Beesley, Thoma and Hestevold (2008) on the grounds that it falls short in validity and consistency, we believe that quantitative investigation can nonetheless still yield useful insights provided the results are deduced with full consideration of possible problems. Our study followed recommendations from Faber and Benson (2017) on improving the structure of the items in the questionnaire, and also verified the constructs in the questionnaire. This study seeks to contribute to the few studies that have used the combination of quantitative and qualitative instruments to measure engineering epistemic beliefs of students from an African university.

# STUDY CONTEXT

Among the teaching challenges which Northedge (2003) highlights as confronting higher education globally is massification, described in particular by Mngomezulu (2015) in regard to the South African context. The challenges spill over to exaggerated focus on delivery, accountability and quality (Northedge 2003). Webb (2012) warns that problems in higher education have caused a shift from educational priorities to business priorities in which the concern is to make the sector economically viable. Moreover, "radical diversification" year by year of the annual student cohort has led to a situation where students arrive in the HE system with differing layers of readiness, and differing cultural standards and beliefs (Brew 2003). For many students, factors that affect these layers of readiness, such as poor social background, poverty, deficient primary and secondary schooling, racial prejudice and medium of instruction, are serious barriers to success in tertiary education (Van der Merwe and Nell 2013). Undoubtedly, too, they affect one's belief about what constitutes knowledge and how it is formulated. Further confusion can occur for the student when, as is often the case, university teachers adopt teacher-centered pedagogies that overemphasize descriptive knowledge, stimulating uncultured beliefs that knowledge is prearranged and uncontestable (Mason 2000). In engineering education, it can be disastrous to use a fixed, traditional teaching pedagogy that discourages transformative and innovative thinking. Therefore, it is important for engineering educators in the African context to understand where their students' knowledge is based, so as to build transformative curriculums and pedagogies that cultivate free and flexible thinking to move the continent forward.

# **OBJECTIVES OF THE STUDY**

This study investigated undergraduate chemical engineering students' epistemic beliefs and

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epistemic motivation using a quantitative instrument with an aide of open-ended questions relating to the engineering epistemic belief items, in a study population where more than 80 per cent of the students are from South African low-income families (University Statistics).

### THEORETICAL FRAMEWORK

Perry's epistemological development philosophy is derived from records that were made of university students' experiences (Perry and Chickering 1997), and his ground-breaking research (Perry 1970) has functioned as the background for a range of subsequent theories (Kuhn 2001; Baxter Magolda 2004; Schommer 1990). The basis of Perry's model is the notion of a personal epistemology embracing an incremental process in which an individual shifts from an angle of knowledge as gathering of facts that are transmitted by an expert to a contextual angle of knowledge (Wheeler and Montgomery 2009). Perry's philosophy is comprised of four comprehensive categories representing students' general thoughts on knowledge: (i) dualism, where knowledge is constructed from a single correct solution held by the person in position of authority; (ii) multiplicity, where knowledge is collected from various ideas; (iii) relativism, where knowledge can be attributed to a specific event; and (iv) commitment, where knowledge is formulated from known data. Several studies conclude in relation to undergraduate engineering students that they complete higher education in lower categories of either multiplicity or dualism (Felder and Brent 2004; Palmer and Marra 2004). Perry's model has attracted particularly strong attention in engineering education in comparison with other theories in epistemology (Felder and Brent 2005).

Schommer (1990) proposed a new approach to assess epistemic beliefs using a quantitative method, which differed from other studies in her contention that epistemic beliefs are not one-dimensional (Schommer 1990; 1993; Schommer and Walker 1997). Schommer concluded that the epistemic belief structure is comprised of five constructs, subsequently reduced to four from factor analysis of results (i) speed of knowledge (knowledge is attained rapidly), (ii) certainty of knowledge (knowledge is truth and cannot be changed or challenged with time), (iii) structure of knowledge (knowledge is formulated by combining different facets to make meaning to a certain phenomenon), and (iv) control of knowledge (knowledge is rigid) (Schommer 1993; Schommer and Walker 1997). The present study is underpinned by these four constructs.

In recent studies there has been a particular focus of attention on discipline-specific epistemic beliefs (Buehl and Alexander 2001; Hofer 2002; Schommer and Walker 1997). Hofer and Pintrich (1997) proposed a multifaceted epistemic beliefs system, parallel to Schommer (1990), which includes the phenomena of knowledge and phenomena of knowing. This

conceptualization of epistemic beliefs established a discipline-specific mechanism to evaluate students' epistemic beliefs in a specified field. Building on Schommer (1990), Hofer (2001) omitted innate ability and quick learning and instead took into account rationalization for knowing. It is no surprise that these factors were excluded because speedy learning and inherent capability can be disregarded as epistemic since they measure student's beliefs about intelligence rather than knowledge (Hofer and Pintrich 1997). The Epistemological Beliefs Assessment for Engineering (EBAE) mechanism established by Hofer (2001) has thirteen items in four constructs: simplicity of knowledge in engineering, certainty of knowledge in engineering. Other researchers have collated various interpretations of knowledge and learning in specialized fields like engineering (Yu and Strobel 2012; Douglas et al. 2012; Faber and Benson 2017). According to Faber and Benson (2017), engineering students view knowledge in engineering as rigid, and their approach to solving design problems is consequently impaired by their reluctance to think broadly.

The Engineering Related Beliefs Questionnaire (ERBQ) established by Yu and Strobel (2012) is a specific epistemic questionnaire, developed from Schommer's (1990) questionnaire, to assess simplicity, certainty and source of knowledge in engineering. In the current study, ERBQ was used to investigate the epistemic beliefs that students from low-income communities embrace in relation to engineering knowledge. The questionnaire items were subjected to validity measures to test the internal consistency or stability of the measuring device over time (Gay 2010). In view of the restricted information that has been provided by studies that have used ERBQ, and of the ongoing contestation about the effectiveness of assessing epistemic beliefs, we undertook to evaluate the logical legitimacy of the engineering epistemic belief items.

Webster and Kruglanski (1994) have suggested that the epistemic motivation could influence one's actions and selections based on whether closure is vulnerable or expedited. The study accordingly also used the Need for Cognitive Closure Scale, which was established to measure interconnections between motivation, data processing and final conclusion (Kruglanski 1990). The instrument has five sub-scale – distress with uncertainty, desire for certainty, decisiveness, preference for command and structure, and close-mindedness – and has been used in multiple studies that have validated its reliability (Webster and Kruglanski 1994). Chinn et al. (2011) note in relation to two of these factors that close-mindedness and distress with uncertainty may inhibit the acquisition of understanding and knowledge. Neuberg, Judice and West (1997) suggest also that person with great need for closure makes conclusions grounded on typecasts and combine different material to present beliefs. In the study, we looked

at the validity and reliability of some of these items.

#### RESEARCH DESIGN

The study was planned according to a correlation model investigating linkage between epistemic beliefs and other variables. The instrument had three sections, which were intended to source students' background, epistemic motivation and epistemic beliefs. In the first section of the instrument, the students were asked to provide details of their personal and social background and the semester that they were currently doing. An ERBQ questionnaire was developed from Yu and Strobel which had three focal issues: certainty of knowledge (meaning knowledge as total truth and not shifting), structure of knowledge (meaning knowledge is modest) and source of knowledge, as described in the frameworks proposed by Hofer (2001) and Chinn et al. (2011). Students were presented with 22 statements about knowledge and learning which they were required to rate on a 5-point Likert scale from 1 (strongly agree) to 5 (strongly disagree). Additionally, the ERBQ had a provision for open-ended responses from the student so as to invite a deeper engagement with the statements in the question. The open-ended response provision also sought to assess the logical validity of the statement items and thereby take account of the contestations in previous studies about the validity of the instruments established to measure epistemic beliefs. The last section of the survey instrument measured epistemic motivation and contained 16 items related to distress with uncertainty and closedmindedness from Kruglanski's Need for Closure Scale (Kruglanski 1990). A 5-point Likert scale from 1 (strongly agree) to 5 (strongly disagree) was used to measure the need for closure.

A total of 77 first-year, 89 second-year and 102 final-year students from the chemical engineering department participated in the study. The sample of students comprised of 57 per cent males and 43 per cent females whom aged between 17 and 24 years. Although the lack of contrasting data from non-South African students could not be identified in the questionnaire, the departmental enrolment statistics showed that there were in any case only six students who were non-South African citizens out of a total enrolment of 435 students. This was not considered as a factor in the present study.

Ethical approval was required and granted by the university's ethics committee. A verbal communication was made to each cohort of students extending an invitation to participate in the study for those who were interested. A time slot to disseminate the questionnaire was sought with relevant teachers in their classes, and the students were briefed on the purpose of the research and assured of anonymity. It was made clear that participation was voluntary and the right to immediate withdrawal if needed was permitted. Students were informed that the aim of the investigation was to collect data on epistemic views and beliefs about different areas of

knowledge. Epistemic questionnaires were distributed to participating students which they were encouraged to complete individually without consulting their classmates, so as to have an objective view on each construct.

### DATA ANALYSIS

Factor analysis was not considered in this case because the study used constructs from existing studies by Yu and Strobel (2011) and Kruglanski (1990). The constructs were not changed in any way, but the phrasing of the statements in each item was edited as per the recommendation by Faber (2015). The data was subjected to statistical analysis to establish internal consistency reliability of the statements in each item. A statistical test on Cronbach's  $\alpha$  for internal consistency was done to measure the correlations between dissimilar items on the same test, as presented on Table 1.

 Table 1:
 Internal consistency of the constructs from Engineering Related Beliefs Questionnaire (Yu and Strobel 2011) and Need for Cognitive Closure Scale (Kruglanski 1990)

Construct (no. of items)	Cronbach α values
Source of knowledge (9)	0.71
Certainty of knowledge (4)	0.73
Simplicity of knowledge (2)	0.52
Close-mindedness (4)	0.70
Distress with uncertainty (4)	0.61

Even though the coefficient lower limit is not stipulated, it is recommended to have the Cronbach's  $\alpha$  coefficient closer to 1, which indicates a greater internal consistency within the range (Gliem and Gliem 2003). However, this research observes the broad principle stipulated by George and Mallery (2003, 231) in which " $\alpha > 0.9$  is excellent,  $\alpha > 0.8$  is good,  $\alpha > 0.7$  is acceptable,  $\alpha > 0.6$  is questionable,  $\alpha > 0.5$  is poor and  $\alpha > 0.5$  is unacceptable". Although the goal is to get  $\alpha$  of 0.8, perhaps  $\alpha$  of 0.7 is a reasonable expectation and equally acceptable. As such, all constructs that fell below the threshold of 0.7 were excluded from the formula  $\alpha = rk/[rk/(k-1)r]$  where "k" denotes the number of measured items' statement and "r" is the average of the inter-item relationships (Gliem and Gliem 2003).

### **RESEARCH FINDINGS**

A total of 77 first-year, 89 second-year and 102 final-year students from the chemical engineering department participated in the research study. The data analysis showed little or no difference within dependent variables such as students' gender (Wilk's Lambda ( $\Lambda$ ) = 0.993; F(3.425) = 1.201; p > 0.05).

Using Cronbach  $\alpha$  test, two items were removed from the results on distress with uncertainty, and three items were eliminated from the constructs closed-mindedness, certainty of knowledge and source of knowledge, since they were found not to be logically reliable. As shown in Figure 1, students in group one were more closed-minded and more inclined to believe that knowledge is truth and cannot be challenged than students in groups two and three. Students in group two seemed to be neutral on knowledge construction but were more open-minded than groups one and three on where engineering knowledge is formulated.



**Figure 1:** Average for each group of students correlated to each the constructs of certainty in knowledge, source of knowledge, and open-mindedness. Each circle on the construct shows the significance of the responses on the 5-point scale

# **QUALITATIVE DATA FINDINGS**

As noted above, the ERBQ had a provision for open-ended response from the student to allow deeper engagement with statements in the questionnaire and to assess logical validity of the statement items. Students were therefore asked to give a brief explanation of each response in the space provided on the questionnaire.

# SOURCE OF ENGINEERING KNOWLEDGE

As originally formulated by Yu and Strobel (2011), there was a list of twelve items that dealt with source of knowledge. However, some items within the constructs were deemed redundant because of their low reliability factor and were discarded from the study. Epistemic beliefs of the students and their logical validity were assessed with eight items, and the qualitative part of the instrument was evaluated.

# In the classroom, when your personal experience conflicts with the "big ideas" in the book, the book is correct

The students seemed to believe in the book, because more than 80 per cent of the respondents rated this item as "strongly agree". Characteristic statements were "The information in the book

is verified by experts" and "The book is trustworthy, it is not like Google, where anyone can load unchecked information for people for read". One student went as far as to say that "Books are always correct because they are written by highly educated teachers". However there were students who disagreed with the item, even though they did not strongly disagree, in comments such as "Some books have old information, which is no longer relevant in our time" and "I have read a book that solved a problem incorrectly and I verified with my lecturer who also got the same answer as me for the problem". Students seemed to understand the statement clearly and there were no context issues that were picked up.

# Engineering books written by experts present the excellent way to learn engineering

Surprisingly, more than 90 per cent of respondents strongly disagreed with this statement. It was expected that, since more than 80 per cent of students on the previous item expressed belief in the books, they would probably agree with this statement. Instead, characteristic comments were "The books are presenting a lot of information and it is not clear enough for me" and "I cannot learn a lot from the book, because it has high level of English" – the latter comment signifying that the academic language used in the book was probably pitched at a higher level that the student could understand, since for most of the students, if not all, English was a second language. Students seemed to share the sentiment that the books are particularly confusing for them. One student said, "I prefer to use the classroom notes and grab engineering terminology from my friends". This suggests that some students learn best from their peers. The students understood the statement in this item very well; there were no issues of misinterpretation that were picked up.

# Conventional engineering ideas should be considered over new ideas

There seem to be a consensus in the responses on this item that new ideas bring in changes that improve the field. One student stated that "We are in the 21st century, hence we need to think as such. We cannot hold on to the things of the past." Another stated, "New ideas are great but we need to find a common ground with the conventional ideas so as to move forward".

# Engineering students learn when a teacher transmits his or her knowledge to them

More than 60 per cent of respondents agreed with this statement, but some noted that there were other means of learning that they consider to be effective. Two contrasting statements were "I trust my lecturers because they are highly educated in this field and they have years of

experience" and "I found that sometimes during the lecture, some lecturers are unable to give us examples we can relate to, because we have never been in the industry". Students commented on how they learn and how they believe they should be taught. The responses were consistent and relevant to the statement, which means the students were clear on what they were being asked. It may be noted that some students did not understand the term "transmit" and used it as interchangeable with the term "teach". One student said "My lecturer transmits well because she knows her engineering stuff".

### You can rely on the information you find in engineering books to be true

As expected, more than 70 per cent of respondents agreed with this statement. The students who agreed took the view that engineering knowledge is continually being developed; therefore, the books are continually being published. As one student put it, "I think it is important to check the latest version of the book because there are changes in the industry hence knowledge is revolutionary". Another student responded that, "The information in the book is verified and I trust it, I rely can rely on it". Some students disagreed, stating that "It depends on which book you are using, I only read engineering books that are recommended in the course learner guide". This response shows that some students rely on the teacher to endorse the book before they can trust it. The item was found to give consistent responses, meaning that the students understood the statement.

### Engineering knowledge is only formulated from an expert's logical thinking

More than 55 per cent of respondents disagreed with this statement. The responses in this item were surprising because previous items suggested that students relied on the subject experts to endorse engineering knowledge sources; however, on this item they seemed to think otherwise. Some students presented their responses as arguments: "The logical thinking can be contested and subjective, so I don't agree" and "You are only an expert if you have failed several times, but also you have got it right several times, so we don't know how many times you got it wrong". The diverging views that they shared, along with some unexpectedly harsh responses suggest that the students found this item confusing.

# First-hand experience is the best way of knowing in engineering

More than 80 per cent of respondents agreed with this statement, citing instances of how this had happed in their lives. There were clearly stated responses such as "I started understanding the 'distillation' calculations after I did the practical in the laboratory and it made things much easier for me" and "Sometimes, you need to experience something on your own before you can

take it seriously, that's how my mind works, I think". Other responses were more neutral, such as, "As much as it [first-hand experience] a good way, but it is not the only way, and certainly not for all of us".

### New engineering knowledge is produced from experimental data

More than 80 per cent of respondents agreed with this statement, making the point that most of the books and journal articles are formulated from experimental data. Two illustrative responses were "Technicians are always carrying out experiments to feed the results back to the theory, also to create new knowledge" and "Experiments are the imitation of what happens in the industry, hence they assist in generating new set parameters and variables for the bigger scale equipment". Students indicated belief in the significance of experimental data in improving processes and thus contributing new knowledge.

### **CERTAINTY OF ENGINEERING KNOWLEDGE**

Seven items in the ERBQ were intended to investigate students' beliefs on certainty of knowledge. Some of the item statements were deemed redundant since they yielded low reliability with other items and the descriptive responses from students were also different. Each descriptive response from the students was utilized to measure the logical validity of the particular item.

#### Classroom engineering problems have one right answer

More than 75 per cent of the students disagreed with this statement, stating that there are different approaches which one can use to solve a particular problem and that all need to be considered even if they sometimes do not yield the same answer. One student said. "The final answer usually carries one or two marks at the end, what is important is how you get to the answer, not the answer as such". Similarly, student said. "If we are solving design problems in class[room] we use different approaches because we don't think in the same way, however we use similar equations and theories but at different stages of the design". Some of the students did agree with the statement but raised the issue of context; one student said "Engineering problems are not similar, when we are doing thermodynamics problems we should get the same answer, but with the design problem we can't get the same answers because there are assumptions in the design and they can't be the same, it's impossible". None of the responses referred to the engineering laboratory problems that students solve during the practical component; it may be advisable to include the laboratory item in the questionnaire as information on this point could enrich the study.

### There is one universal engineering method

More than 95 per cent of students do not agree with this statement. Responses were sort of consistent with the previous statement, where students cited that they do not think in the same way, hence their approach in solving problems is also different. The student responded candidly and said "There are many ways to kill a bird" meaning there are different approaches that can yield to one set outcome. Students' rated responses are consistent with their written descriptive comments, which made this statement to be logically valid.

# Engineering knowledge cannot be subject to change with new observations by individuals

Respondents' beliefs seem to be equally divided on this statement. Some students commented that the observations of a single individual were not enough to effect a change in engineering knowledge and that observations from a collaboration within a group of people or institutions carry more weight to be taken seriously and added as new knowledge. Another comment was that, you need to be well known in the field to contribute new insights. One comment along these lines was "Engineering community will not take me seriously, if I can make a new observation that has a potential to bring change in the field because I don't have any good reputation and I am a student". Other comments were "We work in groups so it is highly unlikely that one student can make a new observation on their own that can effect change in engineering" and "I can make a new observation, however I will have to run that through the laboratory technician and my lecturer".

# Engineering knowledge should be accepted as unquestionable truth

Surprisingly, about 15 per cent of respondents agreed with this statement, believing that engineering knowledge is based on proven facts and theories and therefore cannot be questioned. One response was "Most of engineering facts are based on Law of Physics, and these laws cannot be questioned because they were proved centuries ago". However, most students disagreed with this statement and believed that some engineering aspects need to be challenged. One student quoted the instance of mechanically faulty cars that had been recalled the previous year, and said "Somewhere at the Ford car manufacturing factory, an engineering knowledge was found to be untruthful when, more than 1000 cars were recalled because of mechanical faults". On this item, there was consistency in ratings and descriptive responses from students.

### Engineering theories cannot be argued

More than 60 per cent of respondents were of a belief that engineering knowledge is continually evolving and is therefore constantly under question. One student said "There is a need to improve our processes in the industry, either for safety, production or profit purposes; we need to challenge the design capacity of some equipment hence question the engineering theories". An illustrative comment from one of the students who rated this statement was "I guess it depends, I think you can argue engineering theories that are formulated from mathematical statements, but the ones from Physics, you cannot argue". Students understood this statement well and their ratings were consistent with their descriptive responses.

### DISCUSSION

In the absence of any indications in the literature of meaningful connections between gender differences and epistemic beliefs (Luttrell 1989; Chan 2003) it was decided to omit this as a possible issue for analysis in the overall results for the study.

In relation to levels of study, there was evidence that students in the lower levels of study were more likely than final-year students to believe in "knowledge as truth" rather than believing that "knowledge can be challenged". These results correspond with are in contrast with findings by other researchers (Marra and Palmer 2004; Peng, Tsai and Wu 2006; Wise et al. 2004). However, presumably higher-order thinking skills and the academic experience of final-year students that informs their engineering knowledge can be argued as equally important.

Students across first, second and final years of study showed that they believe that learning only takes place when they are in the presence of the lecturer. This result corresponds unfortunately with what Paul Freire (1985) refers to as a dysfunctional, oppressive system where the teacher retains control and is seen as the omniscient source of knowledge. The result suggests that more than 50 per cent of chemical engineering students are passive in their learning and could be missing learning opportunities if they depend exclusively on their teachers to give them knowledge. This could be disastrous in the engineering field, as the objective is to produce graduates who are independent problem solvers. In contrast with Western countries where there is a strong emphasis on social equality and freedom, the views of a person in authority are usually uncontested in African cultures; for example, a minor is not permitted to question or contend with the views of an adult. Although African culture does have some "positivity and humanistic dimensions, it also has some negative and dehumanizing aspects" (Nussbaum 2003, 8). Our findings correspond with observations by Hofer (2006) and DeBacker et al. (2008) that epistemic beliefs are context-specific. However, this study also

highlights the importance of using simple language when phrasing the questions, as students who use English as a second language may be uncertain about other terminology in the questionnaire.

The study attempts to evaluate the legitimacy and consistency of the epistemic beliefs questionnaire and of epistemic motivation to measure undergraduate chemical engineering students' beliefs. The study used qualitative data as an additional tool in assessing logical validity to explore students' epistemic beliefs on engineering knowledge. The ERBQ used in this study took into account the work of Faber (2015) but used a somewhat larger sample than Faber, whose sample was confined to only 50 students in bioengineering. An additional knowledge contribution to the epistemic field in this study is the generation of data where a combination of quantitative and qualitative tool was used to verify the results. This study agreed with Faber (2015) in finding that there are larger differences between clusters on beliefs about simple knowledge and source of knowledge, which resulted in simplicity of knowledge being discarded from the study.

Although the study attempted to respond to Faber's suggestion that a larger sample should be used, it failed to diversify the cohort of students that were involved in the study. Further work should concentrate on a more diverse sample in the engineering field – for example, including mechanical, electrical, civil and chemical engineering students in one study. In such a sample the responses would not be based on similar experience since the respondents would not all be studying the same curriculum.

### CONCLUSIONS

Currently there is a drive in South African universities to grow enrolment numbers specifically in the fields of engineering, technology, mathematics and science. This drive challenges engineering educators to come up with initiatives that will contribute to the success of the STEM field. Researchers therefore need to continue to explore the views of students about engineering knowledge and their frames of reference in interpreting knowledge in engineering. This study contributes to the current work on understanding engineering epistemic beliefs using both qualitative and quantitative data.

Furthermore, academics need to be aware of the implications of their teaching approaches in case they foster the "omniscient authority factor" in their students. This can have damaging consequences for the learning process because it prevents students from contesting the knowledge delivered to them by the lecturer. A teacher-focused approach is less likely to liberate students because it fails to acknowledge their individual identity. When students are not recognized for themselves, they are unable to maximize their learning opportunities or realize a sense of becoming. The article suggests need to consider a humanizing pedagogy that will promote inclusion of students' social background, feelings and past experiences that will benefit their self-efficacy and their overall learning efficacy.

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