Student Voices regarding Practical Work done in a Mechanical Engineering Laboratory reveals Satisfaction!

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***Abstract-* Students can validly comment on the quality of teaching as they directly experience it and their comments are important to evaluate the nature and quality of educational interventions. The purpose of this paper is to consider student voices regarding practical instruction offered in a Mechanical Engineering laboratory, as this may indicate student satisfaction with the course material. An exploratory study is employed along with descriptive statistics involving quantitative analysis of the collected data. The target population is restricted to undergraduate engineering students enrolled during 2014, who completed a questionnaire survey using an electronic response system. Results indicate that the students perceived the practical experiments conducted in a laboratory to be enjoyable, beneficial, challenging and relevant to the theory covered in a classroom. These results further suggest that students are being exposed to practical work that may contribute to the development of practical skills and graduate attributes required of students to add value to the socio-economic development of South Africa.**

***Keywords-* Perceptions, perspectives; student satisfaction, graduate attributes**

I. INTRODUCTION

"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast". These words, by Leonardo da Vinci, clearly demonstrate that theory and practice must be integrated in order for any student to reach the final destination of demonstrating the achievement of important graduate attributes required by industry today. Although practical skills make up a significant part of an engineering curriculum at a university of technology (UoT), the current emphasis of *engineering education* in South Africa (SA) is to build attributes that will enable graduates to engage in life-long learning. The Central University of Technology (CUT) has prescribed ten student graduate attributes which students must demonstrate through their entire diploma or degree. These include sustainable development, problem solving, entrepreneurship, community engagement, technological literacy, numeracy, teamwork, communication, leadership and technical competence. Many of these attributes may be assessed within a laboratory environment, where engineering students are required to integrate their theoretical knowledge with their practical work [3]. Furthermore, a drive should exist to enable students to apply their theoretical knowledge in practice in order to add direct value to the socio-economic development of their communities, a drive which has been encouraged for many years [1, 2].

CUT offers a National Diploma in a number of engineering disciplines and is therefore mandated by the Engineering Council of South Africa (ECSA) to provide quality *engineering education* programs that will ensure that SA has an appropriate supply of competent engineering personnel with the appropriate graduate attributes [3]. Several of these attributes are assessed within laboratories at CUT, where engineering students are required to integrate their theoretical knowledge with their practical work. Previous research has shown that undergraduate students in an electrical engineering curriculum really enjoyed their practical work scheduled in a laboratory, feeling that the practical work was relevant, challenging and beneficial [2, 4, 5]. Laboratory work, or hands-on activities, can improve student understanding and lead to high student satisfaction with the learning experience [6, 7]. However, this was reported on only for students in an electronic communications course, with fewer results published for undergraduate engineering students in other disciplines at a university of technology. The following research questions therefore arise: What are the perceptions of undergraduate students with regard to practical work done in a Mechanical Engineering laboratory? Do they find the practical work to be enjoyable, relevant, challenging and beneficial?

Student voices are often associated with student feedback or perceptions. Listening to student voices on aspects relating to their educational experiences is an inexpensive, simple and efficient research method to gather information [8] that allows different aspects of the learning environment to be assessed on the basis of the individual student [9]. It must though be noted that student voices are really only personal assessments and views of practices [8]. However, these voices constitute a mental representation of learning activities that affect student's conscious and unconscious choices in the learning environment [10]. Students can validly comment on the quality of teaching as they directly experience it [11] and are important to evaluate the nature and quality of educational interventions [12]. In fact, a key dispositional factor, emerging from the literature that serves to enhance or inhibit student retention is their satisfaction with their course experience [13, 14]. This process of listening to student voices is also a key way to carry out teacher action research [15] which is a very important kind of education research that is especially valuable for demonstrating and evaluating classroom practices and linking theory and research to practice [16].

The purpose of this paper is to consider student voices regarding practical instruction offered in an Applied Strength of Materials laboratory within the Department of Mechanical and Mechatronics Engineering at CUT. Reasons for listening to student voices are first discussed, along with specific practical experiments that have been linked to the theoretical sections within the context of the case study used in this research. The voices of undergraduate engineering students, enrolled for a module in the National Diploma: Mechanical Engineering qualification at CUT were obtained using a questionnaire administered by means of an electronic response system, which forms part of the research methodology. Descriptive results are provided in a series of graphs with succinct conclusions at the end. It is important to note that the author was not involved with the practical work or course material, but simply reports on the voices of students regarding practical work to highlight that it is beneficial in promoting student satisfaction and engagement.

II. BENEFITS OF STUDENT VOICES

Student voices are part of all conversations about teaching, learning, and reform, as educators and policymakers have recognized that not only do students have a right to be heard but they also take the responsibility for education seriously [17]. Student voices or feedback is often obtained in order to determine the students' satisfaction regarding the quality of the education which they have received [13, 14], and has been used to improve the quality of engineering education study programs [18]. Student satisfaction within a specific course or module is an important variable influencing student retention [13, 14], and may lead to students recommending the course or module to fellow students in subsequent academic years. Furthermore, effective feedback is aimed at enhancing learning and teaching by allowing one to compare the actual outcome with the desired outcome [19, 20].

Student voices further allow faculty and students to be empowered with resources to raise the level of academic rigor [21]. Academic rigor is illustrated when students are actively learning meaningful content with higher-order thinking at the appropriate level of expectation in a given context [22]. This level of expectation includes the right graduate attributes which must be demonstrated by students before they enter Industry. Student voices therefore play an important role in determining if ALL the required graduate attributes have been covered in an engineering curriculum.

Listening to student voices can help teachers to reflect critically on their practice to develop policies and practices in the classroom that will more strongly engage students [23]. Student engagement is defined as a two-way street that includes the time and energy students spend on educationally purposeful activities and the degree to which the university gets students to participate in activities that lead to student success [24]. Exposing students to weekly practical work in a laboratory in order to reinforce their theoretical knowledge is considered as student engagement within this study. Obtaining student voices or feedback on this practical work has been effectively used in engineering with regard to new laboratory project designs [25] and in designing a mechanical engineering course for general education [26].

III. CASE STUDY

The module used in this research, Applied Strength of Materials 3 (MSK3), is a compulsory offering or module that forms part of the National Diploma: Engineering: Mechanical qualification, comprising of approximately 24 modules in total. This module is usually offered during the final semester (approximately 14 weeks in duration) of the diploma course and builds on previously acquired knowledge in the field of strength of materials. The purpose of the module is to provide students with a general background of beam theory and to calculate and understand principle stresses and strains in engineering materials. The assessment of the theory is done using a classroom written test, (25% contribution to the semester mark), one main test (40% contribution to the semester mark) and one main final examination. The student's final mark is calculated using 40% of the semester mark and 60% of the final examination. The classroom test covers approximately 20% of the syllabus, while the main test covers 75% of the syllabus with the main final examination covering 100%. The main examination features approximately 40% of applied knowledge, 30% of analysis and 30% of evaluate and design questions.

Four practical assignments (35% contribution to the semester mark) are included in the curriculum to help students to bridge the gap between theoretical and practical instruction. These practical assignments further enable students to exercise engineering judgment and apply it to a practical problem. MSK3 encourages group work where a number of students attend practical sessions together. Table 1 lists the theoretical concepts covered in each unit presented in MSK3, along with a brief description of the practical experiment accompanying the unit. CUT has prescribed ten student graduate attributes which needs to be incorporated into the entire curriculum for the National Diploma. Student competency must be demonstrated with regard to sustainable development, problem solving, entrepreneurship, community engagement, technologically literate, numerate, teamwork, communication, leadership and technical competence. Many of these graduate attributes are assessed in the MSK3 laboratory and are correlated to the practical experiments in the discussion which follows.

The first two practical experiments require students to measure the deflections of a beam under various loads. The experimental results are compared to theoretically calculated results, where after students should comment on the findings and evaluate any discrepancies or similarities. The practical experiments are designed to test the students' ability to work and communicate effectively with others, collect and organize information and perform specific calculations. Student graduate attributes of teamwork, technical competency and numeracy are therefore assessed.

Students are expected to measure the strain on a pressure cylinder (with known dimensions and material properties) under various internal pressures as part of the third practical experiment. The practical experimental results are compared with theoretically calculated results and conclusions should be made with regard to perceived differences and why they exist. This practical experiment is designed to strengthen the students' ability to organize and manage themselves and their activities responsibly while using science and technology effectively. CUT student graduate attributes of numeracy (calculating specific parameters using predefined equations) and technological literacy (in terms of effectively using different mechanical technologies) are hereby assessed.

Table 1: Linking theory with practice in a Applied Strength of Materials laboratory

Key theoretical concepts in the syllabus	**Practical experiments in the laboratory**
Slope and deflection of beams	1. Measure the deflections of a cantilever beam and determine the elastic modulus based on the measured and calculated data 2. Measure the deflection of a simply supported beam and calculate the radius of curvature
Circumferential and radial stresses in thick cylinders	3. Measure the strain in a thick cylinder due to an internal pressure and determine the corresponding principle stresses.
Buckling of struts	4. Measure the deflection for various loads and determine the crippling load for various end conditions

The fourth practical experiment requires students to compare the results of experimental crippling loads with loads theoretically predicted by the Euler equations. A relationship between the experimental crippling loads for the various end conditions is to be determined and evaluated by the students. This practical experiment is aimed at enhancing student's ability to critically evaluate information regarding a given problem, and to communicate this problem effectively to others using mathematical and written communication skills. CUT student graduate attributes of numeracy, communication and problem solving is therefore assessed.

IV. METHODOLOGY

An exploratory case study is employed along with descriptive statistics of the quantitative data. An exploratory case study is ideal for analysing what is common and different across cases that share the same key criteria. Furthermore, it is an appropriate tool to obtain preliminary enquiries [27]. Student voices regarding the benefits, relevance and practicality of the practical work done in a laboratory are sought. Descriptive statistics are used as the results are interpreted with regard to specific African engineering students enrolled at CUT.

Quantitative analysis is used as it brings a methodical approach to the decision-making process, given that qualitative factors such as "gut feel" may make decisions biased and less than rational [28]. The target population is restricted to African undergraduate engineering students enrolled for MSK3 at CUT during 2014 (n = 32). An electronic response system was used in a classroom environment at the end of the semester to obtain student perceptions on specific questions relating to the practical work done in the laboratory. Closed-ended questions, featuring Likert scales, were used based on previous research which focused on student perceptions of practical work done in a laboratory [5, 29, 30].

V. RESULTS AND DISCUSSIONS

The purpose of this paper is to consider undergraduate engineering student voices regarding practical work done in a MSK3 laboratory. This is divided into three sections; one focusing on whether students feel that the practical work was enjoyable and beneficial (see Figure 1); one focusing on whether students felt that the practical work was challenging and relevant (see Figure 2); and one focusing on student recommendations regarding the practical work (see Figure 3).

The results presented in Figure 1 indicate that 77% (42% strongly agrees and 35% agrees) of the 32 respondents to the questionnaire in the MSK3 class really enjoyed the practical experiments which were done in the laboratory. Although 81% (53% strongly agrees and 28% agrees) of the respondents agree that the subject was a valuable learning experience, only 68% (34% strongly agrees and 34% agrees) would recommend the subject to other students. 72% (38% strongly agrees and 34% agrees) of the respondents were convinced that the practical experiments helped them to apply new knowledge to solve engineering problems while almost all students were convinced that the experiments gave them a better understanding of the theory (48% strongly agree and 34% agree). The last two responses are especially important as the graduate attribute of problem solving and the ability of a student to apply their theoretical knowledge in practice is highly prioritised by ECSA.

Figure 2 categorizes three questions which may be linked to the relevance and difficulty of the practical experiments. Although 48% of the respondents were of the opinion that the practical experiments were not too difficult, the majority (16% strongly agrees and 59% agrees) found it challenging. 96% (73% strongly agree and 23% agree) of the students agreed that the practical experiments were indeed relevant to the theory done in the classroom. Practical work which is relevant to theory and accessible to students, can go a long way towards increasing the enjoyment and sense of achievement of students [33]. It is important for students to 'learn by doing' and it has been found that active student engagement in authentic practical work, which is relevant to Industry, benefits student learning [34]. Subsequently, it may be stated that these results tend to suggest that the practical experiments promoted student engagement with the theory

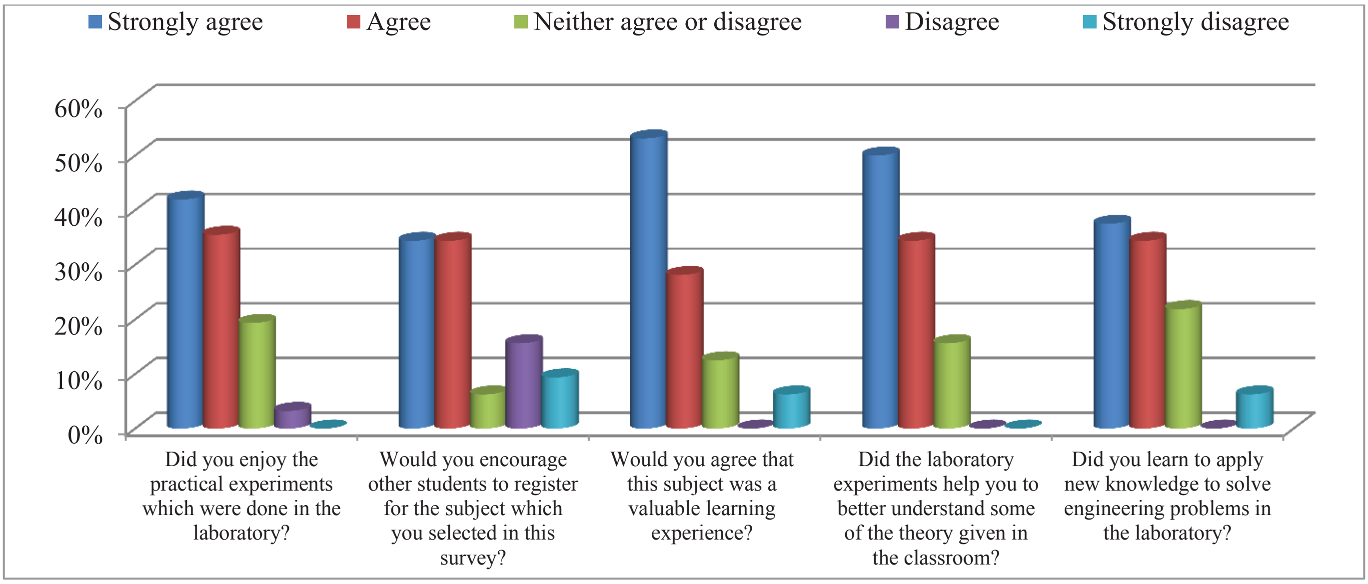

Figure 1: Student voices regarding the benefits of practical work done in the MSK3 laboratory

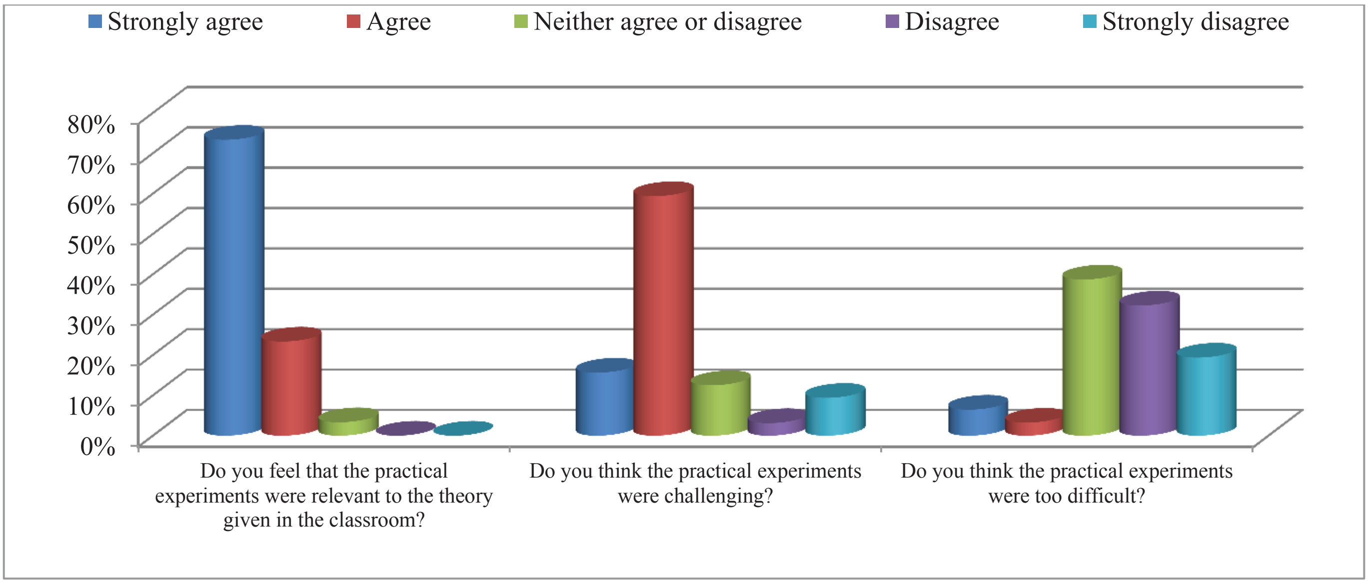

Figure 2: Student voices regarding the relevance between the practical and theoretical work in MSK3

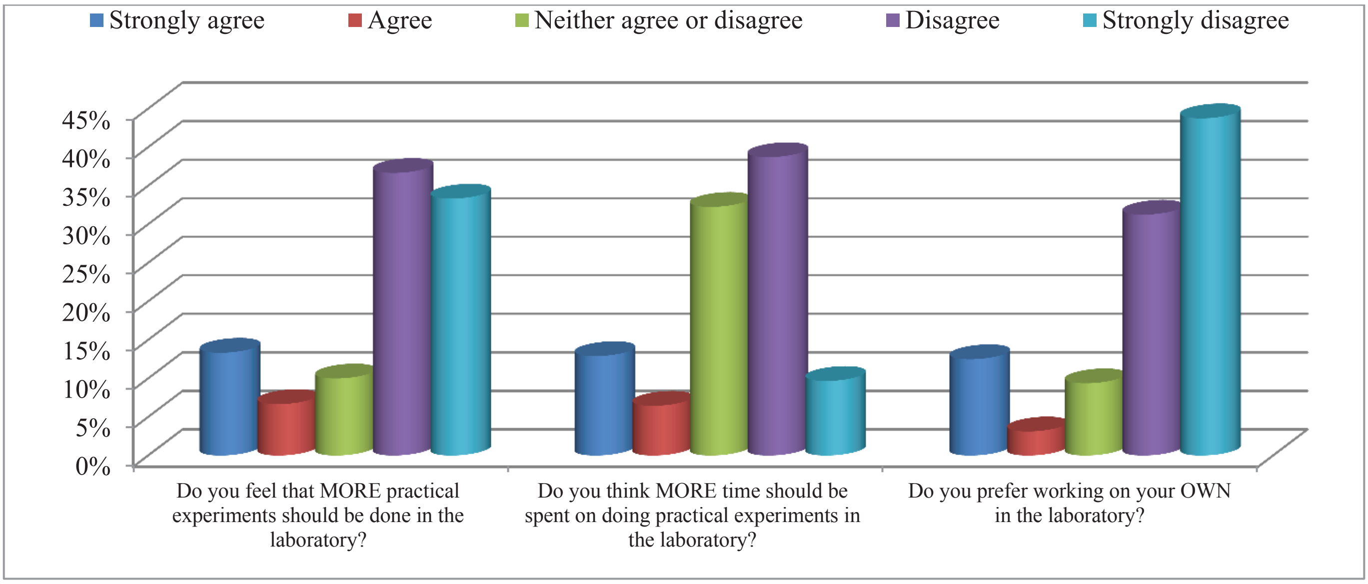

Figure 3: Student recommendations regarding the practical work

From the data presented in Figure 3, it is evident that the majority of respondents felt that the number of practical experiments completed in the laboratory were sufficient (37% disagree and 33% strongly disagree that more practical experiments should be conducted). More than 40% of the respondents were of the opinion that more time should not be spent on doing practical experiments in the laboratory. This is rather a discrepancy when considering the results of the other questions. It may be that students feel that the current timetable which schedules 3 hours per week in the laboratory is sufficient for them to grasp the link between theory and practice. Additional research into why students feel this way is warranted. On the more positive side, 75% of the respondents prefer group work, as shown by the responses to the question of working on your own in the laboratory. This may assist students to develop the important graduate attribute of teamwork, which is advocated by the International Engineering Alliance [35] and based on the Washington, Sydney and Dublin accords.

VI. CONCLUSIONS

The purpose of this paper was to consider student voices regarding practical instruction offered in an Applied Strength of Materials laboratory within the Department of Mechanical and Mechatronics Engineering at a UoT. The specific practical experiments that are currently undertaken by undergraduate engineering students in this field of study were outlined and linked to the specific theoretical sections within the syllabus of this module.

The results indicate that the majority of students enjoyed the practical experiments completed in the laboratory, contributing to student engagement with the course content. The practical experiments were relevant to the theory and applicable in encouraging problem solving, communication and teamwork which are fundamental graduate attributes that engineering students need to demonstrate. These results suggest that student satisfaction has been achieved with the practical work in this module and has led to student engagement as they have devoted time and energy to this educationally purposeful activity.

Additionally, important student graduate attributes of numeracy (calculating specific parameters using predefined equations), technological literacy (in terms of effectively using different mechanical technologies) and technical competency (collecting and organizing technical information) were also assessed in the laboratory (see Table 1). A total sum of seven different graduate attributes have been incorporated into the practical instruction which forms part of this engineering curriculum, thereby giving Mechanical Engineering students the opportunity to demonstrate their acquisition. The successful acquisition or demonstration of these graduate attributes and the indication of student satisfaction and engagement has the potential to empower graduates to enter industry with the ability to contribute to the socio-economic development of their communities and of South Africa.

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