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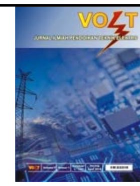

IDENTIFYING LEARNING STRATEGIES AMONG FIRST-YEAR ENGINEERING STUDENTS

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Abstract

The Williamson's self-rating scale for self-directed learning (SRSSL) questionnaire is applied to determine which learning strategies first-year African engineering students have adopted at the start of a problem-based learning module that is designed to promote self-directed learning (SDL). This approach can help academics to better identify "who" their students are, thereby helping them to leverage and improve on current learning strategies to try and enhance student engagement. A requirement for becoming a great teacher in one's field of study is to come to know your students cognitively, affectively and culturally. Many different cultures have strongly embedded identities that would form and shape student learning strategies. The purpose of this article is to identify what self-perceived learning strategies engineering students have adopted from their school education, by using a standardised questionnaire. Student perceptions regarding their own levels of SDL, as well as their expectations and actual achievements of academic success are also presented. The primary purpose of the problem-based learning module that is used in this study is to give engineering students the opportunity to develop managerial skills as the module involves much teamwork, where imaginary companies are formed with the goal of designing and constructing specific projects for real industry-based clients. A time-lag study is used where quantitative data are collected using a standardised questionnaire. Results indicate that 77% of females report high levels of SDL, while only 66% of males do so. No significant correlation exists between the self-reported scores of the students and their final grades. However, the three most reported learning strategies include interactive teaching and learning sessions, simulations and educational interactive technologies. It is recommended that academics encourage SDL among first-year engineering students by helping them to identify appropriate learning strategies that can help them to enhance their engagement with the course and subsequent academic success.

Keywords: Gender differences, problem-based learning, Williamson's SRSSDL questionnaire

INTRODUCTION

"True knowledge exists in knowing that you know nothing" (Brainy Quote, 2020). These words by the Greek philosopher Socrates, who lived in the 4th century BC, emphasise that when we acknowledge that we know nothing, we actually possess true knowledge. This is certainly true of the universe that we as humans almost know nothing about. It has been stated that the universe is vast and constantly in motion, while humans are small entities with limitations (Junghare, 2018). A similarity exists in higher education where some academics know very little about the students in their classrooms. This is indeed a limitation to improving student engagement that is vital for success.

In order to teach effectively, we must know our students cognitively, affectively and culturally (Kester, 2019). Cognitive covers beliefs and knowledge of stimuli and their assessment; affectively refers to emotions; and behavioural is the tendency to behave in a certain way, reacting to one's own emotions and cognitions (D' Souza et al., 2019). This last aspect (namely behavioural) is aligned to one's cultural heritage and is related to one's learning strategies. Learning strategies refer to particular behaviours (Derakhshan et al., 2015) that are formed over a period of time where various social and cultural factors contribute to the development of different strategies (Kim, 2018). It must be noted that many South Africans have very strongly embedded cultural identities that would form and shape their learning strategies. Compared to the United States, South African culture is more collectivistic, as it tends to encourage social cohesion, group pride and loyalty, collective action and collective distribution of resources (Van Aarde et al., 2017).

Learning strategies are, for the most part, unobservable (Derakhshan et al., 2015) and require some or other form of diagnosis to identify. Furthermore, some academics fail to appreciate the importance of the students and their experiences in the learning environment (Cotterill, 2015). This includes failing to diagnose, or coming to know, what learning strategies students bring into the classroom, especially first-year engineering students who have just completed their high school career. Most of these students need support to develop learning strategies that are appropriate to higher education (Stacey et al., 2015), which may contribute to improving student engagement and student learning. Indeed, evidence supports the idea that academic student support for first-year engineering students is more imperative than for other students in higher education (Veenstra, 2008), especially due to the fact that they may never have been exposed to engineering during their high school career.

The nature of this academic support may vary among genders. Gender differences in engineering education have been associated with the special nature of engineering. A variety of predictors, including men's mathematical and spatial abilities and women's verbal abilities and lower self-assessment, confidence and self-efficacy (De Winter and Dodou, 2011). It has also been shown that, in general, females outperform males in both reading and writing performance (Clarke and Hyde, 2016) and in attention, word and face memory and social cognition tests (Ingalhalikar et al., 2014). Therefore it may also be found that female students self-report different learning strategies as compared to male students.

One diagnostic method that can be used by academics to identify the learning strategies of their first-year engineering students involves the use of the Williamson self-rating scale of self-directed learning (SRSSDL). This self-rating scale was originally developed to assess self-directed learning (SDL) behaviour that is different from the measuring of perceptions and readiness for SDL (Ayyildiz & Tarhan, 2015). The SRSSDL has been used in higher education to determine which skills, including learning strategies, would be required for life-long learners (Swart, 2018b).

The purpose of this article is to primarily identify what self-perceived learning strategies first-year African engineering students adopted by using the Williamson SRSSDL. This may better assist academics to leverage and improve on current student learning strategies that may impact on their academic success and especially in problem-based learning modules requiring SDL. The following research questions are posed:

- What percentage of female students report high SDL scores compared to male students?
- What percentage do learning strategies account for in the self-reported SDL scores of first-year engineering students?
- Which learning strategies have first-year engineering students adopted that are related to SDL?
- What ratio of engineering students report high academic expectations when registering for a module in higher education that requires SDL?

The paper starts with a discussion of the importance of learning strategies that are vital for SDL and that need to be determined by academics at the start of a semester. The context of the study is then given along with the methodology. A number of figures are shown in the results with related discussions of the quantitative data.

LEARNING STRATEGIES VITAL TO SDL

According to Weinstein and Underwood (1985), learning strategies are an indication of all processes involved in how people learn. These involve various ways in which people use information to create meaning in life. Some strategies are note-taking, focused attention, positive study attitude, creation of relationships, drawing implications, time management, as well as reflecting on their knowledge gaps, monitoring tasks and directing learning activities to integrate new information. Learning strategies usually involve active learning and management of all learning processes with the aim to enhance study practices, understanding, application of knowledge and students' overall performance. On this note, Hernández-de-Menéndez et al. (2019) point out that active learning (an interactive teaching and learning method) involves student engagement in meaningful and collaborative activities. In other words, students set clear learning objectives, understand, reflect on and think critically about what they do. Kamaruzaman et al. (2019) compiled a conceptual framework for the development of 4th Industrial Revolution (4IR) skills as required for future engineers. They emphasise that there is priority to particular skills that prepare these students for future 4IR challenges. The first skill they mention is 'analytical thinking and innovation' and the second preferred skill is 'active learning and learning strategies' (Kamaruzaman et al., 2019).

Moreover, learning strategies assist in the development of SDL skills as students should take responsibility and manage their own learning processes (Weinstein and Underwood, 1985). Sulasiwi et al. (2019) concur that the 'mastery of the learning strategy has to do with SDL skills', as the student should be able to apply relevant learning strategies in several situations. This is in particular true for solving real-world engineering problems. Similarly, Ainscough et al. (2020) highlight that students who have knowledge of various learning strategies, have the opportunity to select an appropriate strategy when faced with difficult and sometimes challenging learning tasks. Furthermore, the role of lecturers or university teachers is to provide active learning opportunities by challenging students to explore, analyse and evaluate their ideas and solve complex problems rather than informing students only (Le & Do, 2019). Part of this repertoire is 'creativity, originality and initiative' as well as 'complex problem solving' as essential skills for the 4IR (Kamaruzaman et al., 2019). In Engineering, this involves reflecting on previous experiences, making decisions and determining the relevance of a strategy to address an open-ended and real-world problem. To provide the correct active learning opportunities requires academics to first know what learning strategies have been adopted by their students.

UNDERSTAND LEARNING STRATEGIES

Knowing what learning strategies our students bring into the classroom relates to the theory of multiple intelligence by Gardner and the zone of proximal development by Vygotsky. The multiple intelligence theory refers to the idea that there are eight different types of intelligence that interact and complement each other as a person learns new skills or answers problems (Gardner, 2011). One of these eight types is called interpersonal intelligence that necessitates one to understand other people. This requires an academic to know and understand the learning strategies of his or her students in higher education so as to provide any necessary corrective action. According to Vygotsky (1978), the 'Zone of Proximal Development' refers to the place where cognitive functions are in the process of maturation. It refers to the gap between what a student can and cannot do that can be bridged through the help of others or technology, such as YouTube videos. Again, this requires an academic to know and understand the learning strategies of students, especially in terms of what they can and cannot do (their actions), so that the right amount of guidance and support may be given to bridge this gap. This is often called scaffolding that refers to the temporary and dynamic support within the zone of proximal development (Setyowati et al., 2020).

CONTEXT OF THIS STUDY

Professional Practice I (better known as FIAP 172 by students and academics) is a compulsory module in the Bachelors of Engineering (BEng) degree for all engineering students at the North-West University (NWU) in South Africa. These students are around 18 years old, having just completed their high school career. Many of them come from rural backgrounds where they had no exposure to engineering. The primary purpose of FIAP 172 is to give engineering students the opportunity to develop managerial skills as it involves much teamwork, where imaginary companies are formed with the goal of designing and constructing specific projects for real industry-based clients.

Some of these projects include a working hovercraft, a pet-dipping station and a recycling machine (Swart, 2018a). Electrical, mechanical and chemical engineering students work together in this module that spans an entire year. The syllabus is split across two semesters that are each 14 weeks in duration. Engineering students obtain 24 credits when they successfully complete FIAP 172; thereby, indicating that they have devoted 240 notional hours to this module.

Registered first-year African engineering students are required to complete a practical workshop induction program at the start of the first semester (usually scheduled in March of each calendar year). It is held over a period of one week, where students must attend three different practical sessions of eight hours each. This induction program covers aspects relating to safety, electrical motor operations, welding, fitter and turning practice and general electrical principles. This empowers students with the required theoretical and practical knowledge they will need to apply when engaging with the design and construction of a physical project. This aligns with research by Biggs (2003) who states that quantitative stages of learning (acquiring knowledge) should occur first, followed by qualitative stages of learning (putting knowledge into practice). It also aligns with the learning cycle of Kolb (1984) and the alternative framework for developing performance objectives devised by Gagne (1962). Students are rotated among different practical laboratories, as the facilities are not large enough to accommodate all the registered students at the same time. An indemnity form is signed by the students thereby releasing the university from any legal action that may arise due to negligent student behaviour.

A list of possible projects from industry clients is then shared with groups of students in April. Each group is made up of six students, who need to identify a possible project and prepare a PowerPoint presentation on what they think would be required to complete it successfully. The facilitator then awards a specific project to a group based on their presentation, which should highlight their understanding of the project.

A concept design and detailed design are submitted in May, with a detailed budget in June. Students physically work on their project for about three months, with a final test and evaluation at the end of September. An exhibition in October opens their work to public scrutiny and especially to the industry clients who requested the projects. Regular communication occurs between the facilitator and groups using the institution's learning management system, which is built on SAKAI (Swart, 2015) and contributes to furthering student engagement outside of the classroom (Swart, 2016).

RESEARCH METHODOLOGY

A time-lag study is used where quantitative data are collected using the Williamson SRSSDL (Williamson, 2007). Time-lag studies are useful for providing information about differences in the behaviour of successive generations as they progress through a single point in the life span (Baird et al., 2012). In this study, the behaviour of three different generations, or cohorts, of students is analysed with regard to SDL, with special emphasis on their learning strategies.

The target population is relatively large (n= 1,048) as it encompasses all undergraduate registered students for FIAP 172 over a three-year period, thereby negating the use of a sampling technique. Quantitative data involves the student's self-rating scores obtained from the Williamson SRSSDL for 2015, 2016 and 2017 along with their final grades achieved in the FIAP 172 module. This SRSSDL was completed by students during the induction programme held in March.

The Williamson SRSSDL features 58 questions with 12 questions specified per subsection (Williamson, 2007). These subsections are termed Awareness, Learning Strategies, Learning Activities, Evaluation and Interpersonal Skills, all associated with SDL. Awareness relates to students' understanding the factors that contribute to SDL, while Learning Strategies requires students to select specific strategies that they currently use. Learning Activities requires students to select specific activities that they currently use, while Evaluation helps to reveal specific student attributes with regard to how they monitor their learning. Interpersonal Skills list specific skills that students need to demonstrate. The validity and reliability of this questionnaire has been noted in previous research (Cadorin et al., 2013, Behar-Horenstein et al., 2018) and is well-suited to discovering what learning strategies, activities and attitudes students have adopted.

The results of the Williamson SRSSDL are usually divided into three categories. These include low-level SDL (students who score less than 140 on the rating-scale), moderate-level SDL (students who score between 140 and 220 on the rating scale) and high-level SDL (students who score more than 220 on the rating-scale). This score is determined by summing the responses of the students to the 58 questions that each feature a five-point Likert scale (1 = never; 2 = seldom; 3 = sometimes; 4 = often and 5 = always). Students need to indicate their current behaviour with regard to specific statements. For example, in the learning strategy section, a statement is made: "*I participate in group discussions*". If a student answers "always", then a value of 5 is awarded to this student. Answering "always" for all 12 questions in a subsection equates to a score of 60. Answering "always" to all 58 questions in the Williamson SRSSDL equates to a maximum score of 290.

These scores are then paired with the final grades of the students and then classified according to gender in a MS EXCEL sheet. A Pearson correlation is then performed between the total scores for each subsection of the Williamson SRSSDL and the student's final grades. Average and mode values for each subsection are also provided. A contrast of the results between the five subsections of the Williamson SRSSDL is then made in order to determine the percentage contribution of learning strategies to the overall SDL score of the students. Finally, student expectations regarding their final grade for the module are analysed.

A number of questions were asked prior to the 58 standard questions in the SRSSDL to determine the student profile. These questions are relevant to this study and included gender, age, year group, average student grade for their final year in high school and student expectation regarding their final grade for the module FIAP 172. The results and discussion section start with three of these results relating to the student profile.

RESULTS AND DISCUSSIONS

Profile of the students

The student profile of the first-year African engineering students registered for FIAP 172 reveals that males still dominate in numbers (ratio of 4,4:1), as has been found in other research relating to both first-year and senior engineering students (Swart, 2019). The majority of the students are 18 years old, having just completed their high school career where they obtained their matric certificate (NQF Level 4 qualification in South Africa). The average age for Grade 12 learners in South Africa who obtain such a certificate is 18 years (Kruger and Sonono, 2016). The majority of these students are also enrolling for the first-time in this module, with a small number (less than 25) of repeating students.

Gender representation and final grades

Fig. 1 contrasts the number of males to females with regard to their level of SDL. This is a self-reported value based on their responses to the Williamson SRSSDL. A larger percentage of females report a high level of SDL as compared to males. This is consistent for all three calendar years, where the average difference is 11% (average of 66% for males as compared to 77% for females).

Fig. 2 presents a scatter plot of the students' self-reported scores for SDL versus their final grades awarded at the end of the module. No significant correlation exists between these two variables. However, a concentration of dots is observed within the black rectangle, which represents students who reported a high SDL score (>220) and who achieved more than 50% for their final grade (the required percentage to successfully complete the module). Noteworthy are the two highest student SDL scores of 288 who achieved 70% and 86% respectively. The final pass rate for all three years was 91.1%.

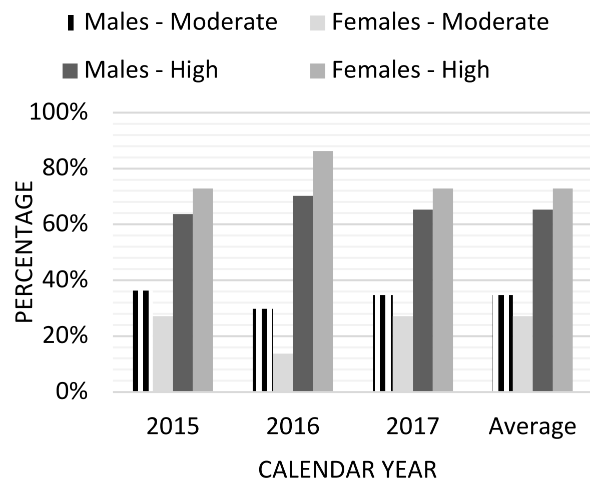

Fig. 1: Contrast between males and females' self-reported levels for SDL

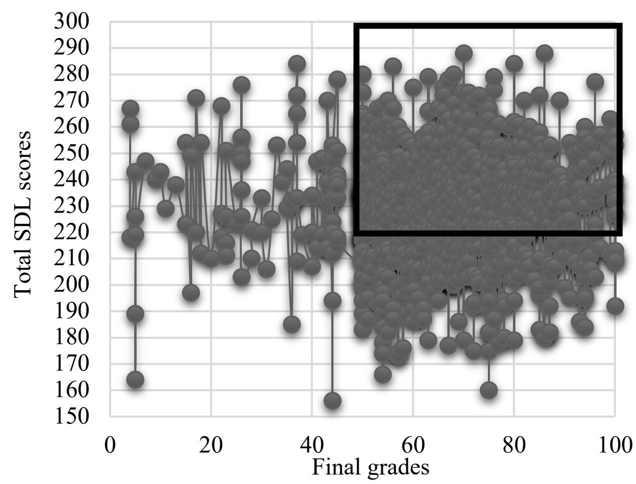

Fig. 2: Scatter plot of the students' self-reported scores for SDL and their final grades

Learning strategies percentage of SDL

Table I shows the Pearson correlation values along with specific contributions. No statistically significant correlations were found between any of the subsections of the

Williamson SRSSDL and the final grades of the students. However, a weak significant result was found for learning strategies (0,083 significant at the 0.1 level). Learning strategies also revealed the lowest average value of 3,72 (derived from a 5-point Likert scale where 5 represents "always"). All standard deviations are below 0,46, which suggests that the data are not heavily spread between 1 and 5 on the Likert scale. The results further indicate that Learning Strategies account for 19.42% of the total SDL scores of the students, being the lowest contribution of all five subsections.

TABLE I. Correlations and contributions

	Awareness	Learning strategies	Learning activities	Evaluation	Interpersonal skills
Correlations	0,029	-0,054	-0,022	-0,026	-0,044
Sig.	0,341	0,083	0,472	0,403	0,150
Averages	4,07	3,72	3,77	3,81	3,77
STD	0,37	0,42	0,41	0,46	0,46
Mode	4,08	3,58	3,67	3,83	3,83
Percentage contribution	21,27 %	19,42 %	19,74 %	19,95 %	19,66 %

Due to these statistics, the learning strategies reported by the students were singled out for consideration. Another reason for singling out the learning strategies is due to the fact that they are based on first-year students' experiences in high school that may not be very relevant to higher education. Academics would need to ascertain what these strategies are to guide students into adopting additional learning strategies for higher education and especially for problem-based learning modules that students would not have encountered during their schooling career. A third reason relates to the fact that learning strategies are, for the most part, unobservable, as noted in the introduction of this article and would thus require academics to seek student perceptions of them.

Learning strategies identified

Fig. 3 presents the 12 questions asked with regard to learning strategies in the Williamson's SRSSDL questionnaire. The three most reported strategies that are preferred by these students include interactive teaching and learning sessions (Question 23), simulations (Question 24) and educational interactive technologies (Question 30).

These are evident by considering the "Often" and "Always" selection. These strategies link directly with active learning, as students need to interact personally with different sessions, simulations and educational technologies to achieve specific learning outcomes. Active learning can furthermore be directly connected with SDL, as noted by Weinstein and Underwood (1985) in the literature review. The three most cited reported strategies, in order of priority, that are not preferred by the students, include concept mapping (Question 29), role play (Question 22) and using case studies (Question 25). These are evident by the black colour section of the horizontal column that represents the selection "Never".

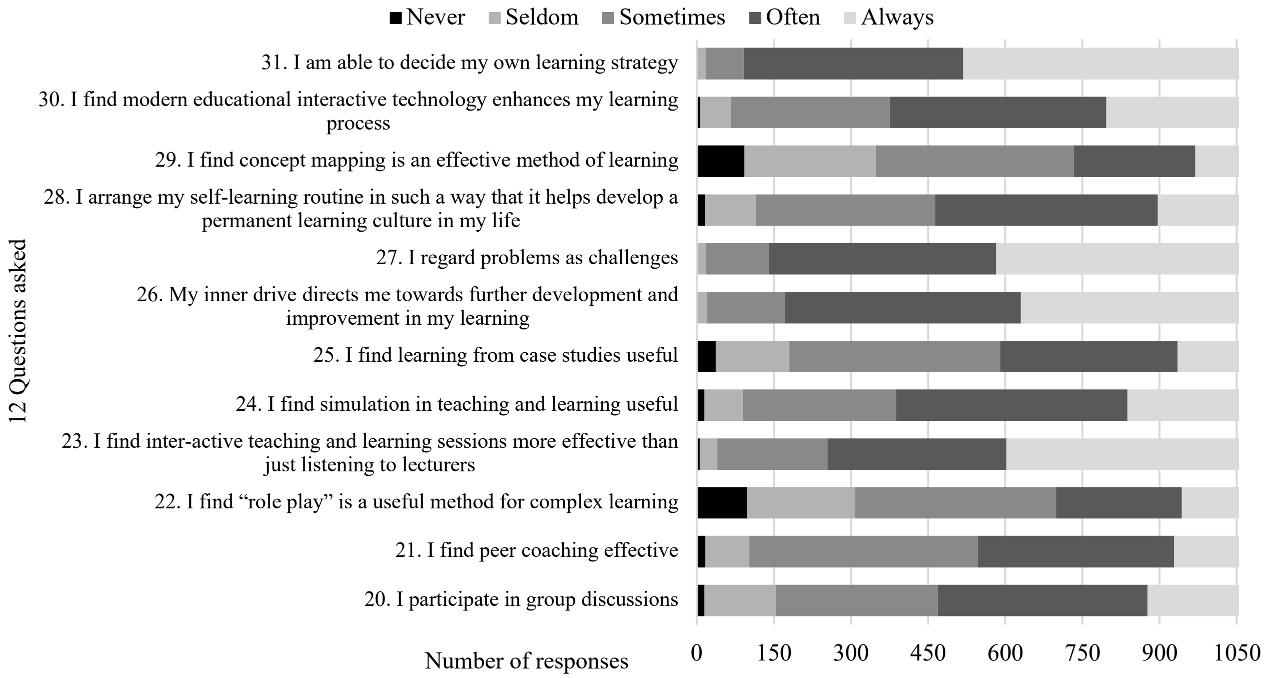

Fig. 3: Learning strategies reported by the engineering students

Fig. 4 shows that 500 male students (58,9% of all male students) underestimated their final grade by 10% or more, while 111 female students did this (58,1% of all female students). Only 18,6% of all male students overestimated their final grades, while 22% of all female students did this. These results indicate that one out of every three first-year African engineering students tends to have high academic expectations when entering a module based on the development of SDL in higher education and that may be influenced by his/her previous academic results in high school.

Academics need to know what prior beliefs, emotions and actions students bring to their classrooms in order to further enhance student engagement. This is a hallmark of a good teacher that aligns itself with the scholarship of teaching and learning, that has, as its primary aim, the improvement of student learning by evolving one's own teaching practice to become a great teacher (Swart et al., 2016).

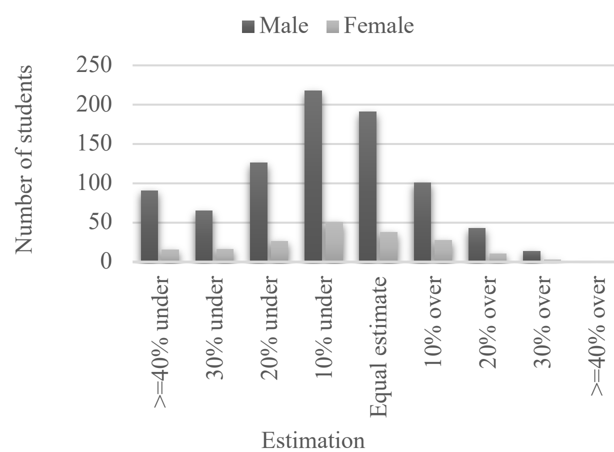

Fig. 4: Histogram of student academic achievement expectations

The results of this study have shown that academics can identify the beliefs (specifically levels of SDL and academic expectations) and actions (specifically learning strategies) of their students by using a survey instrument (specifically the Williamson SRSSDL) at the start of their module. In this way, they can keep investigating their own teaching practice so as to align it with the type of students that enter their classrooms. They may also be able to provide additional academic student support to help students adopt additional learning strategies required in higher education.

The following research questions were answered:

- What percentage of female students report high SDL scores as compared to male students?
  - 77% of females reported a high SDL score, compared to 66% of males who did so;
- What percentage do learning strategies account for in the self-reported SDL scores of first-year engineering students?
  - A constant average contribution of 19.42% over a three-year period.
- Which learning strategies have first-year engineering students adopted that are related to SDL?
  - The three most reported strategies include interactive teaching and learning sessions, simulations and educational interactive technologies.
- What ratio of engineering students report high academic expectations when registering for a module in higher education that requires SDL?
  - One out of every three first-year African engineering students did so.

CONCLUSIONS

The value of "knowing" who our students are is vitally important, so that we may adapt our teaching strategies to better align with student learning strategies. It is recommended that academics make use of the Williamsons SRSSDL questionnaire, or a similar standardised questionnaire, at the start of a semester to identify these learning strategies. The results of the questionnaires should then be discussed with the students to further help them identify additional learning strategies that could enable them to become more self-directed learners. Positive benefits can only be accrued in terms of enhanced student engagement as academics seek to leverage current adopted learning strategies that can help lead students to academic success. First-year engineering students will continue to require support to develop learning strategies that are appropriate to higher education and especially to modules that are based on problem-based learning. It should be the responsibility of each academic to provide this needed academic support, so that we may gain some true knowledge about the students to whom we have been entrusted.

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