34th Australasian Association for Engineering Education Conference
3 - 6 December 2023 – Gold Coast, QLD

Gender Relationships with Student Experience in the Engineering Teaching Laboratory: A Multi-Learning Domain Gender Correlation Between Student Evaluation Scores and Perceived Learning

Sasha Nikolic and Thomas Suesse
Faculty of Engineering & Information Sciences, University of Wollongong
Corresponding Author Email: sasha@uow.edu.au

ABSTRACT

CONTEXT

Student evaluation data has been recognised for a very long time as being beneficial if used correctly and very dangerous if applied without understanding. With males being the largest proportion of students in engineering classrooms in many countries, do the voices of female students get drowned out, leading to feedback cycles tailoring better learning experiences for males?

PURPOSE OR GOAL

This study explores the relationships between the way students evaluate laboratory experiments, facilities and demonstrators in relation to perceived learning.

APPROACH OR METHODOLOGY/METHODS

This is accomplished using the Laboratory Learning Objectives Measurement instrument considering laboratory learning across the cognitive, psychomotor and affective domains. A multi-level statistical analysis is conducted at an Australian university.

ACTUAL OR ANTICIPATED OUTCOMES

The study finds that the evaluation relationships for males and females differ, and the implications are discussed. Multi-domain learning in the laboratory is also perceived to occur by students across both genders.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This work adds to the academic literature the risks of looking at student evaluation scores blindly. An analysis is needed to uncover the key messages and limitations of the instrument. This work provides a platform for a larger study that can attract a larger female sample.

KEYWORDS

Engineering, Gender, Laboratory, SET

Introduction

It is well recognised that across Australasia and other parts of the world, male students make up a dominant proportion of the engineering cohort, something that the engineering community would like to change (Docherty et al., 2020). Across Australia, Canada, Japan and the United States, female participation in engineering is stubbornly low, ranging from 2 - 18% (Strachan, Peixoto, Emembolu, & Restivo, 2018). The imbalance at the university level ultimately ends up being reflected in low industry participation. With technology-based jobs growing rapidly, a high percentage of the world population is not accessing career opportunities that are increasingly becoming available (Gómez, Tayebi, & Delgado, 2021). As a result, researchers have tried to understand ways of undoing this imbalance.

It has been well established that women specialising in STEM (Science, Technology, Engineering & Maths) face many barriers along their engineering student and career pathway (Morelock, 2017). It is, therefore, important for universities to try and eliminate barriers related to education to encourage retention. As it is difficult to get women to start a STEM degree, it then becomes essential to ensure those students are retained (Webley, 2022). Statistics from the USA suggest that just under half don’t complete their STEM degree, highlighting that university administration does not have in place effective strategies to improve the situation (Bunnell, 2021). This is not to say that the higher education community is not trying. Many initiatives have taken place, and have been successful, but many are hindered by the need for continuous high resource load and effort (Lagesen, Pettersen, & Berg, 2022). There have also been many studies exploring female perceptions of their degree (Aznar-Mas, Atarés Huerta, & Marin-Garcia, 2021) and decisions to undertake engineering (Long, Cunningham, Dart, Whiteford, & Dawes, 2022; Sasha Nikolic, Suesse, & Goldfinch, 2018).

This study contributes to the field within the scope of the engineering laboratory. Preparing students for engineering practice is an important step towards career-readiness. The laboratory can support the foundational skills needed for engineering careers (Feisel & Rosa, 2005). An advantage of the laboratory is that across the diverse range of learning activities, students have the opportunity to develop a holistic range of skills across the cognitive, psychomotor and affective learning domains (S. Nikolic, Suesse, Jovanovic, & Stanisavljevic, 2021). The development of laboratory skills plays an important role in engineering accreditation and can support the development of personal attributes essential for professional practice (Lal et al., 2017). Therefore, we need to ensure that we are providing a quality laboratory experience.

There are many ways to ensure quality. Within engineering, the accreditation process supports this, but this is a complex time-consuming process and is not a source of regular feedback (Engineers Australia, 2008). A more easily attainable measure of teaching quality, that universities across the world have gravitated towards, is measuring quality through the use of student evaluation instruments. This has resulted in the increased use of student evaluations towards measuring teaching quality, supporting faculty decisions, institutional accountability, institutional reputation and regulatory purposes (M. Lloyd & Wright-Brough, 2022; Soto-Estrada, Wellens, & Gómez-Lizarazo, 2018).

However, the use of student evaluations to control quality is contentious. This is because student evaluation data has been recognised for a very long time as being beneficial if used correctly and very dangerous if applied without understanding (Aleamoni, 1999).

Work from an earlier study by the authors (S. Nikolic et al., 2021) suggests that in a laboratory setting, strong correlations exist between perceived learning and evaluation ratings. However, the data analysis provided no gender separation. Research by authors such as Gupta, Garg, and Kumar (2018) and Price, Svensson, Borell, and Richardson (2017) highlight that females tend to evaluate metrics such as teacher quality differently compared to males. With females a minority group within engineering, it is of interest to investigate whether the gender imbalance can influence the messages being delivered through the evaluations. That is, are the quality relationships regarding perceived learning the same? If they are not, this can encourage further research to investigate the implications.

This study will explore this by using the Laboratory Learning Objectives Measurement (LLOM) instrument (S. Nikolic et al., 2021) in which students rate their ability against the laboratory learning objectives. They do this twice before they start the first laboratory session and again at the end of the final laboratory session. The changes in the way students rate themselves are used to determine perceived learning.

With the teaching laboratory playing an important educational role, this study attempts to answer the research question '*What are the gender-based relationships between student evaluations in the laboratory and perceived learning?*'. Findings will allow the engineering community to better understand the messages being delivered by male and female students in the laboratory.

Method

Data Collection Overview

Data collection occurred between 2015 and 2017 within the School of Electrical, Computer and Telecommunications Engineering at the University of Wollongong. This research received ethics clearance with Human Ethics Project Number 2014/156.

This study uses the same research design as applied in the work by Nikolic et al. (2021b). The difference being the data analysis as determined by the research question. The study implements a multi-section design. Multi-section designs, dividing a large course into multiple sections covering the same content but taught with different instructors, is a more reliable way of understanding the relationships between student evaluation data and teaching effectiveness (Stehle et al., 2012). This is one of the benefits of the laboratory approach. Courses generally have multiple laboratory classes with a range of teaching staff, but with constant syllabus, experimentation, assessment and other learning content across all instances. This is a strength of the implemented research design**.**

The Instruments

The research involved the use of the LLOM instrument to define the laboratory objectives for each course used in this study. With the LLOM being holistic, this covered learning objectives included and not included in a courses formal list of learning objectives. The 24 LLOM learning objectives across the three domains are separated into four different groupings. COG-A represents cognitive analytical skills and COG-W represents cognitive writing skills. The cognitive domain has been separated into two separate classifications determined by factor analysis. The psychomotor skills are represented by PSYCH, and affective skills represented by AFFECT. Details of the instrument and attributes that represent each classification can be found in S. Nikolic et al. (2021) and S. Nikolic et al. (2023).

As outlined in Section 2, most common student evaluation instruments do not have a laboratory focus. For this reason, laboratory specific evaluation instruments were used. The **Laboratory Experience Survey** used for evaluating the laboratory experience is outlined in Sasha Nikolic, Ritz, Vial, Ros, and Stirling (2015). Student perceptions of the laboratory experiments are referred to as LAB, consisting of the averages from 3 statements. Student perceptions of the laboratory facilities are referred to as FACIL, consisting of the averages from 3 statements. Together, the responses provide valuable insights on student perspectives of the overall laboratory experience. The **Laboratory Demonstrator Survey** is used for measuring teaching quality as outlined in Sasha Nikolic, Vial, Ros, Stirling, and Ritz (2015). This instrument consists of five questions relating to functions required of a demonstrator. As outlined in the introduction there are many variables that can influence, evaluation scores. The scope of this study is to only explore relationships with perceived learning.

Experimentation

The teaching evaluation is concentrated only on teaching assistants called laboratory demonstrators, also known as casual or sessional teachers in Australia. This was implemented due to the fact that they are the main source of face-to-face contact in the laboratory (O'Toole et al., 2012). All laboratory demonstrators are Master's or PhD research students that undergo competitive recruitment and undertake in-depth training. The overwhelming majority of demonstrators are international students. Details of the related survey questions and training processes are outlined in Sasha Nikolic, Vial, et al. (2015). This study is limited to laboratory classes with either one or two laboratory demonstrators. One demonstrator is used for class sizes up to 20 students (average 15) and two demonstrators are used for class sizes up to 39 students (average 35). The lead demonstrator is referred to as DEM1, and the assistant (if applicable) is referred to as DEM2. The number of demonstrators in a class is determined by class size. For each laboratory class, students had the same demonstrator for every experiment (between 5 and 12 experiments in each course).

Nine courses covering all four years of the engineering degree and postgraduate coursework were selected to participate in the study. At the start of the first laboratory session for each course the LLOM self-assessment was undertaken. Students were requested to rate their capability on a scale from zero to five, with zero reflecting no knowledge to five reflecting extreme confidence. Students that agreed to participate in the research were requested to include their student number for identification. At the end of the last laboratory session the LLOM self-assessment was repeated, and the Laboratory Experience and Laboratory Demonstrator surveys were conducted. To minimise disruption of class time, for most courses' participation was only offered to some of the scheduled laboratory classes.

Participation in the study was voluntary and offered to 473 students. Due to anonymity required as part of the ethics application, limited demographic information was collected. The data for the self-assessments, student evaluations and laboratory exam were matched using the student number and then the responses were de-identified by a research assistant for analysis. All responses were analysed when made anonymous. A total of 358 completed responses were matched across the different courses with 295 male and 63 female. The school has a very low ratio of female students, and the sample represents the student population at the university. No student identified with any of the other gender options made available. Therefore, this study concentrates only between the descriptors of male and female. While the sample of females may be low, the conditions reflect the situation describing the need for this research.

Analysis

Each laboratory class for each course had consistent factors such as assessment, structure, experiment, and facilities. The benefit of having consistent factors allowed for the implementation of a rigorous multi-level analysis. This was carried out between laboratory classes of the same course as well as between courses. The benefit of using the multi-level analysis is that it allows for a close examination of the impact of the demonstrator as other conditions are constant. For example, the multi-level model analyses the impact of one demonstrator teaching repeated classes in the same course and across different courses. This scenario of having students within a laboratory class, and laboratory classes within a course, is a typical example of hierarchal data, for which typically a multi-level model, with levels students, laboratory classes and courses, is used for the statistical analysis (Berkhof & Kampen, 2004; Sasha Nikolic, Suesse, McCarthy, & Goldfinch, 2017). Not accounting for the hierarchal structure of the data might lead to incorrect statistical results. This is because standard errors would be either under or overestimated (Moerbeek, 2004). The multi-level model allows for the calculation of an accurate representation of the relationship between two different variables. For this study it is of particular interest to determine if a statistically significant relationship is found between two variables.

The platform R and the R package lme4 was used for the statistical analysis, in which the estimated effects of the learning domains on teaching evaluations and p-values of the multilevel model will be presented.

Limitations

As data is collected only from subjects within the fields of electrical, computer and telecommunications engineering, the scope of the results is limited to laboratories from those disciplines. Results may be different if applied in laboratories of different engineering disciplines. Different culture, experiences and attitudes towards student evaluations at different universities may possibly provide different results. The results are also specific to the instruments used.

It must be noted that the sample size for female responses was very low (but the sample size reflects the male to female ratio at the university) and this could lead to non-significant effects. Therefore, the significance in relationship for non-significant items could change with a larger female sample. It is important to note that the hypothesis testing ensures that the conclusions are valid and represents the student population at the university regardless of the sample size. Due to the small female sample size, a direct comparison of statistical differences was not undertaken. This will be explored in future work when the sample size can be increased.

Results

The student evaluation scores from the teaching (DEM1 and DEM2), experiment (EXP) and facilities (FACIL) questions were compared against the differences in self-assessment scores (before and after) using the LLOM instrument across the cognitive (COG-A and COG-W), psychomotor (PSYCH) and affective (AFFECT) domains. The data is presented as relationship between variables (the effect of one score increase of each learning domain compared to LAB, FACIL, DEM1 and DEM2), indicator of significance and standard error. Statistically significant relationships are shown in red. For example, the relationship between LAB (student evaluation scores of the laboratory experiment) and COG-A (measures 1-7 in the cognitive domain) in TABLE 1 is represented as 2.779 meaning that for every one score increase in the COG-A domain the LAB score is expected to increase by 2.779. The maximum score for any evaluation variable being 100. The relationship between perceived learning and evaluation scores for males is shown in Table 1 and for females in Table 2. If each table is looked at separately, differences in the correlations between how males and females evaluate the laboratory experiments, facilities and demonstrators can be seen. The data shows some major differences in both the magnitude of the effect size, and which relationships are statistically significant.

Discussion

When male and female data is combined, as outlined in S. Nikolic et al. (2021), statistically significant relationships across almost every variable are found. When separated by gender, as investigated in this study, relationships differ. Considering the primary research question, *What are the gender-based relationships between student evaluations in the laboratory and perceived learning?* differences in magnitude, and the variables that hold statistically significant relationships can be seen. The data does suggest that males and females have different priorities when evaluating.

Some of the key observations are:

Laboratory Experiments (LAB vs Perceived Learning): Perceived learning across all three domains had a significant influence on the way males evaluated the quality of the experiments. This was the only relationship for males that was holistic across all three domains. This suggests that the most accurate representation to understand male perceived learning is through their ratings of the experiments. In contrast, there was no major significant relationship with the female evaluation scores apart from cognitive-writing skills. This would suggest that the quality and type of experiment is very important for shaping male learning.

Laboratory Facilities (FACIL vs Perceived Learning): Perceived learning in the cognitive domain was found to be the only significant relationship to the way male students evaluated the laboratory facilities.

Table 1: Male Responses – Relationship Between Student Evaluation and Perceived Learning. Statistical Analysis based on Multilevel Model on Student Evaluation with Fixed Effects: 'Perceived Learning', 'hardware' and 'level' and random effects: semester, course, demonstrator and lab class.

Evaluation	COG-A	COG-W	PSYCH	AFFECT
LAB	2.779 * (1.150)	3.503 **(1.074)	2.207 * (1.031)	2.708 * (1.230)
FACIL	2.448 * (0.983)	2.414 **(0.912)	1.422 (0.891)	1.338 (1.051)
DEM1	1.728 . (1.042)	2.008 * (0.9748)	2.279* (0.926)	1.494 (1.114)
DEM2	3.799 * (1.490)	2.350 . (1.338)	2.943 * (1.299)	1.710 (1.541)

Significance codes p-values * < 0.05 ** < 0.01 *** < 0.001 . < 0.10

Table 2: Female Responses – Relationship Between Student Evaluation and Perceived Learning. Statistical Analysis based on Multilevel Model on Student Evaluation with Fixed Effects: 'Perceived Learning', 'hardware' and 'level' and random effects: semester, course, demonstrator and lab class.

Evaluation	COG-A	COG-W	PSYCH	AFFECT
LAB	3.254 (2.241)	3.773 * (1.730)	2.275 (2.037)	-0.360 (1.878)
FACIL	7.050 ** (2.515)	8.165***(1.725)	5.378 *(2.327)	3.653 . (2.149)
DEM1	5.576 * (2.184)	4.784 * (1.852)	4.595 * (1.940)	4.585 * (1.765)
DEM2	10.648 ** (3.116)	7.643 * (2.804)	7.592 **(2.704)	5.738 * (2.746)

Significance codes p-values * < 0.05 ** < 0.01 *** < 0.001 . < 0.10

This relationship was stronger for female students and also extended across to the psychomotor domain. While the affective domain would not be considered as technically significant for the female cohort, the p-value of less than ten percent would suggest that it could become so with a much larger sample. This suggests that females express learning via the quality of the facilities, rather than via experimentation. This might be because the laboratory helps provide females with the confidence to engage with and better appreciate the instruments used for experimentation. This confidence factor is discussed more further on.

Demonstrators (DEM1/2 vs Perceived Learning): Male students predominately rated the quality of their demonstrators (DEM1 is the primary demonstrator, and DEM2 the assistant if class size warranted one, see Method for more information) by their perceived learning in the psychomotor domain. The cognitive relationship was not consistent across both demonstrators. Of interest the data shows that learning in the affective domain played no significant role in evaluating the demonstrators. This suggests experiments that provide the best hands on learning experiences are best reflected in demonstrator evaluation scores. In contrast, the female ratings showed that perceived learning across all domains was very important to the way they rate the laboratory demonstrators. The difference in perceived learning in the affective domain is of most interest; especially because it is flagged as significant with a low sample of females when compared to the large sample of males. Overall, the large coefficients, and the statistical confirmations across all three domains highlight that demonstrator teaching effectiveness is most accurately predicted by female perceptions of learning.

The differences discovered in this study suggest that the majority voice of males could possibly drown out the signals being expressed by the female minority cohort on what a quality laboratory experience looks like. For example, male students might rate a demonstrator highly, and that demonstrator might be seen as an exemplar. However, the data suggests that other influencing factors other than learning are more significant in determining that rating. That exemplar may not be supportive of aiding female learning. This result is not unexpected. Females have different priorities on their way into an engineering degree (Sasha Nikolic et al., 2018), why not during. Different minority groups experience courses in different ways (Wilson & Wilson, 2020).

Synthesising the observations with the literature a number of connections can be made that can provide meaning to the results. The holistic perceived learning correlations between females and demonstrator ratings can possibly be linked to the differences in the way males and females seek help and interact with others. For example, it has been found that female students apply more collaborative learning strategies, are better accustomed to learn from others, asks more questions and seek help from other students with higher frequency (N. A. Lloyd & Szymakowski, 2017; Mbarika, Sankar, & Raju, 2003; Stump, Hilpert, Husman, Chung, & Kim, 2011; Thinnyun, Lenfant, Pettit, & Hott, 2021; Vujovic & Hernández-Leo, 2022). This suggests that the female students may interact with the demonstrators more and gain more value from their presence than males, resulting in strong holistic correlations. This raises the importance of developing robust training programs for demonstrators (Sasha Nikolic, Vial, et al., 2015; O'Toole et al., 2012) to ensure that they are providing the supportive environment needed to facilitate learning. As we already know that demonstrators play an important role in influencing student experience (Sasha Nikolic et al., 2017), this new finding suggests extra focus in demonstrator training should be placed on techniques to better support female learning preferences. Based on the literature such social support mechanisms would be vital for all learning modes within the engineering degree. Possibly, this is why males may have a strong perceived learning correlation to the experiment scores. If males are seeking less support from the demonstrators, independent learning behaviour may be seeking experimentation design and procedure clarity that ensures success without the need from greater input from others. This requires further investigation.

The correlations with the affective domain are of further interest. Moreover, the affective correlation with laboratory facilities may have also been statistically significant with a larger female sample. The affective domain represents feelings and attitudes and is connected to LLOM items such as collaboration (characterising/responding), motivation (valuing), and ethics (organising) (S. Nikolic et al., 2021). Such affective attributes have been linked in other studies such as: the benefits for females to interact with engineers to avoid career doubt (Male & MacNish, 2015); the greater connection female students have towards subjects that skew towards ‘values’, ‘understanding’ and ‘social-connectedness’ (Stoakley, Brown, & Matthee, 2017); and that female students provide higher ratings than male students on motivational and supportive scales (Gupta et al., 2018). Combined, this highlights the importance of increasing the awareness of affective learning objectives in engineering, something that the traditional laboratory can provide given its suitability for collaborative engagement. This is in contrast to the cognitive focus emerging of what a successful engineering laboratory education looks like (Sasha Nikolic, Ros, Jovanovic, & Stanisavljevic, 2021) and the impacts this could have on the female learning experience.

The most dominant relationship was for cognitive-writing learning with females, the only objective to hold a statistically significant relationship with all variables. This could suggest that the laboratory is an environment that supports the development and confidence of technical writing skills for females. While research indicates that gender does not significantly affect technical writing skills , females can lose confidence of their writing capability beyond primary school (Pajares, 2003). The multitude of assessments targeting technical writing used in the laboratory (Sasha Nikolic et al., 2021) may help bring out that confidence.

Conclusion

The goal of this study was to answer the research question ‘*what are the gender-based relationships between student evaluations in the laboratory and perceived learning?*’. The goal of this question was to explore if the messages of the female voice differed and could be drowned out in a minority position. The study indeed found substantial differences suggesting that this could be possible.

Both male and female students perceive learning occurs across all three domains, highlighting the multitude of benefits laboratory implementations can have. This is in contrast to the concentration of research focus with only the cognitive assessment component of laboratory implementations. The next step forward is to explore student evaluation correlations with real learning, a much more complex activity. A future study with a larger female sample size is needed to confirm the weight of these findings to overcome the limitations discussed in Method.

References

Aleamoni, L. M. (1999). Student Rating Myths Versus Research Facts from 1924 to 1998. *Journal of Personnel Evaluation in Education, 13*(2), 153-166.

Aznar-Mas, L. E., Atarés Huerta, L., & Marin-Garcia, J. A. (2021). Students have their say: factors involved in students' perception on their engineering degree. *European Journal of Engineering Education*, 1-19. doi:10.1080/03043797.2021.1977244

Berkhof, J., & Kampen, J. K. (2004). Asymptotic effect of misspecification in the random part of the multilevel model. *Journal of Educational and Behavioral Statistics, 29*(2), 201-218.

Bunnell, P. D. B. (2021). *A Quantitative Research Study of Attrition and Retention Rates Among Female Graduate Science, Technology, Engineering and Mathematics (STEM) Students and Alumnae.* (29257604 Ph.D.), Capitol Technology University, Ann Arbor. ProQuest One Academic database.

Docherty, P. D., Fox-Turnbull, W. H., Naswall, K., Homewood, A., Bradley, H., Zaka, P., & Chase, J. G. (2020). The contribution of gender segregated secondary education on the progression to engineering. *Australasian Journal of Engineering Education, 25*(1), 31-38. doi:10.1080/22054952.2020.1788254

Engineers Australia. (2008). G02 Accreditation Criteria Guidelines. In *Education Programs at the level of Professional Engineer*.

Feisel, L. D., & Rosa, A. J. (2005). The Role of the Laboratory in Undergraduate Engineering Education. *Journal of Engineering Education, 94*(1), 121-130.

Gómez, J., Tayebi, A., & Delgado, C. (2021). Factors That Influence Career Choice in Engineering Students in Spain: A Gender Perspective. *IEEE Transactions on Education*, 1-12. doi:10.1109/TE.2021.3093655

Gupta, A., Garg, D., & Kumar, P. (2018). Analysis of Students' Ratings of Teaching Quality to Understand the Role of Gender and Socio-Economic Diversity in Higher Education. *IEEE Transactions on Education, 61*(4), 319-327. doi:10.1109/TE.2018.2814599

Lagesen, V. A., Pettersen, I., & Berg, L. (2022). Inclusion of women to ICT engineering – lessons learned. *European Journal of Engineering Education, 47*(3), 467-482. doi:10.1080/03043797.2021.1983774

Lal, S., Lucey, A. D., Lindsay, E. D., Sarukkalige, P. R., Mocerino, M., Treagust, D. F., & Zadnik, M. G. (2017). An alternative approach to student assessment for engineering–laboratory learning. *Australasian Journal of Engineering Education, 22*(2), 81-94.

Lloyd, M., & Wright-Brough, F. (2022). Setting out SET: a situational mapping of student evaluation of teaching in Australian higher education. *Assessment & Evaluation in Higher Education*, 1-16. doi:10.1080/02602938.2022.2130169

Lloyd, N. A., & Szymakowski, J. (2017). Student experiences in first-year engineering classrooms – exploring issues of gender in an Australian programme. *Australasian Journal of Engineering Education, 22*(1), 23-31. doi:10.1080/22054952.2017.1365328

Long, S., Cunningham, S., Dart, S., Whiteford, C., & Dawes, L. (2022). *Why do students choose to study engineering?: Insights from a large-scale institutional survey*. Paper presented at the 33rd Annual Conference of the Australasian Association of Engineering Education (AAEE).

Male, S. A., & MacNish, C. (2015). Pilot exploration of gender inclusivity of engineering students' exposure to engineering practice in an Australian university. *Australasian Journal of Engineering Education, 20*(2), 135-144. doi:10.1080/22054952.2015.1116176

Mbarika, V. W., Sankar, C. S., & Raju, P. K. (2003). Identification of factors that lead to perceived learning improvements for female students. *IEEE Transactions on Education, 46*(1), 26-36. doi:10.1109/TE.2002.804407

Moerbeek, M. (2004). The consequence of ignoring a level of nesting in multilevel analysis. *Multivariate Behavioral Research, 39*(1), 129-149.

Morelock, J. R. (2017). A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement. *European Journal of Engineering Education, 42*(6), 1240-1262. doi:10.1080/03043797.2017.1287664

Nikolic, S., Ritz, C., Vial, P. J., Ros, M., & Stirling, D. (2015). Decoding Student Satisfaction: How to Manage and Improve the Laboratory Experience. *IEEE Transactions on Education, 58*(3), 151-158. doi:http://dx.doi.org/10.1109/TE.2014.2346474

Nikolic, S., Ros, M., Jovanovic, K., & Stanisavljevic, Z. (2021). Remote, Simulation or Traditional Engineering Teaching Laboratory: A Systematic Literature Review of Assessment Implementations to Measure Student Achievement or Learning. *European Journal of Engineering Education, 46*(6), 1141-1162.

Nikolic, S., Suesse, T., & Goldfinch, T. (2018). *Engineering Students at Day Zero: Selection and Concerns by Gender.* Paper presented at the 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE).

Nikolic, S., Suesse, T. F., Grundy, S., Haque, R., Lyden, S., Hassan, G. M., Daniel, S., Belkina, M., & Lal, S. (2023). Laboratory learning objectives: ranking objectives across the cognitive, psychomotor and affective domains within engineering. European Journal of Engineering Education, 1-20. https://doi.org/10.1080/03043797.2023.2248042

Nikolic, S., Suesse, T., Jovanovic, K., & Stanisavljevic, Z. (2021). Laboratory Learning Objectives Measurement: Relationships Between Student Evaluation Scores and Perceived Learning. *IEEE Transactions on Education, 64*(2), 163-171. doi:10.1109/TE.2020.3022666

Nikolic, S., Suesse, T., McCarthy, T., & Goldfinch, T. (2017). Maximising Resource Allocation in the Teaching Laboratory: Understanding Student Evaluations of Teaching Assistants in a Team Based Teaching Format. *European Journal of Engineering Education, 42*(6), 1277-1295.

Nikolic, S., Vial, P. J., Ros, M., Stirling, D., & Ritz, C. (2015). Improving the Laboratory Learning Experience: A Process to Train & Manage Teaching Assistants. *IEEE Transactions on Education, 58*(2), 130-139. doi:http://dx.doi.org/10.1109/TE.2014.2335712

O'Toole, P., Crampton, A., Rayner, G., Beavis, A., Beames, S., Meier, P., & Cox, J. (2012). Demonstrator development: Preparing for the Learning Lab. *The Australian Council of Deans of Science,* 1-76.

Pajares, F. (2003). SELF-EFFICACY BELIEFS, MOTIVATION, AND ACHIEVEMENT IN WRITING: A REVIEW OF THE LITERATURE. *Reading & Writing Quarterly, 19*(2), 139-158. doi:10.1080/10573560308222

Price, L., Svensson, I., Borell, J., & Richardson, J. T. E. (2017). The Role of Gender in Students' Ratings of Teaching Quality in Computer Science and Environmental Engineering. *IEEE Transactions on Education, 60*(4), 281-287. doi:10.1109/TE.2017.2696904

Soto-Estrada, E., Wellens, A., & Gómez-Lizarazo, J. (2018). Student course evaluation: a process-based approach. *Australasian Journal of Engineering Education, 23*(2), 83-94. doi:10.1080/22054952.2018.1557099

Stoakley, A., Brown, N. J., & Matthee, S. (2017). *The role of a humanitarian focus in increasing gender diversity in engineering education.* Paper presented at the 28th Annual Conference of the Australasian Association for Engineering Education (AAEE 2017).

Strachan, R., Peixoto, A., Emembolu, I., & Restivo, M. T. (2018, 17-20 April 2018). *Women in engineering: Addressing the gender gap, exploring trust and our unconscious bias.* Paper presented at the 2018 IEEE Global Engineering Education Conference (EDUCON).

Stump, G. S., Hilpert, J. C., Husman, J., Chung, W.-t., & Kim, W. (2011). Collaborative Learning in Engineering Students: Gender and Achievement. *Journal of Engineering Education, 100*(3), 475-497. doi:https://doi.org/10.1002/j.2168-9830.2011.tb00023.x

Thinnyun, A., Lenfant, R., Pettit, R., & Hott, J. R. (2021). *Gender and engagement in CS courses on Piazza.* Paper presented at the Proceedings of the 52nd ACM Technical Symposium on Computer Science Education.

Vujovic, M., & Hernández-Leo, D. (2022). How Do Table Shape, Group Size, and Gender Affect On-Task Actions in Computer Education Open-Ended Tasks. *IEEE Transactions on Education, 65*(4), 533-543. doi:10.1109/TE.2022.3143715

Webley, P. (2022). *Can engineering education be altered to improve gender equality within STEM workplaces?* Paper presented at the 33rd Annual Conference of the Australasian Association of Engineering Education (AAEE), Sydney.

Wilson, K. F., & Wilson, K. (2020). How do students in different minority groups experience first-year engineering? *Australasian Journal of Engineering Education, 25*(1), 66-78. doi:10.1080/22054952.2020.1796044

Acknowledgements

We would like to thank the students who participated in this study.

Copyright statement