2019

The effect of using a project-based learning (PBL) approach to improve engineering students' understanding of statistics

Fionnuala Farrell
Technological University Dublin, fionnuala.farrell@tudublin.ie

Michael Carr
Technological University Dublin, michael.carr@tudublin.ie

Recommended Citation

Fionnuala Farrell, Michael Carr, The effect of using a project-based learning (PBL) approach to improve engineering students' understanding of statistics, Teaching Mathematics and its Applications: An International Journal of the IMA, Volume 38, Issue 3, September 2019, Pages 135–145, DOI:10.1093/teamat/hrz005

Teaching Mathematics and its Applications (2019) **38**, 135–145
doi:10.1093/teamat/hrz005 Advance Access publication 26 August 2019

The effect of using a project-based learning (PBL) approach to improve engineering students' understanding of statistics

Fionnuala Farrell[†] and Michael Carr[‡,*]
[†]*School of Mechanical and Design Engineering, Technological University Dublin*
[‡]*Multidisciplinary Technologies, Technological University Dublin*

[*]*Corresponding author. Email:* michael.carr@dit.ie

[Received November 2018; accepted June 2019]

Over the last number of years we have gradually been introducing a project based learning approach to the teaching of engineering mathematics in Dublin Institute of Technology. Several projects are now in existence for the teaching of both second-order differential equations and first order differential equations. We intend to incrementally extend this approach across more of the engineering mathematics curriculum. As part of this ongoing process, practical real-world projects in statistics were incorporated into a second year ordinary degree mathematics module. This paper provides an overview of these projects and their implementation. As a means to measure the success of this initiative, we used the SALG instrument to gain feedback from the students. The SALG online tool - Student Assessment of their Learning Gains - https://salgsite.net/; is a free course-evaluation tool that enables third-level educators to gather feedback specifically focused on what the students gained through the learning exercise they experience. It can be used to measure students' learning gains. Pre-developed surveys are available which can be modified and are stored in a repository for ease of access. Results are anonymous and there is the ability to download comments and basic statistical analysis of responses. Feedback from the survey points to a large increase in understanding of the material coupled with an increase in confidence. In addition we outline some of the limitations of our initial implementation of this approach and what we hope to improve on for the next academic year.

1. Introduction

A 2013 study of First Year Experience (FYE) in the eight third level institutions in the Dublin Region found that one of the key problem areas identified by academics consistently across all the eight institutions was the lack of 'student engagement' (Roper *et al.*, 2013; Cusack *et al.*, 2013). This lack of engagement can result in both poor performance and poor retention. Since September 2012, incoming first year students to higher education in Ireland have studied a revised mathematics curriculum (Project

Maths) in second level (Jeffes *et al.*, 2013; Prendergast *et al.*, 2017). This new approach to the teaching and learning of mathematics in Ireland aims to situate mathematics in everyday contexts where possible, so that students will be better able to understand the uses and relevance of mathematics. In particular, there has been a huge increase in the amount of statistics taught at second level. Much of the material taught in the early years of mathematics is not explicitly mapped at that point to modules or applications in later years, making it difficult for students to understand the importance of what they are learning at this initial stage in their careers. Sometimes it can be challenging for mathematics lecturers to find applications that are easily understood by students in these early years. From research it is observed that successful service teaching of mathematics relies heavily on a ‘sufficient supply of discipline related problems’ (Yates, 2003). Also, the importance of ‘dual responsibility’ between the teacher and learner in order to strive for excellence in mathematics teaching should be considered (Kaur, 2010).

This research on teaching mathematics, the findings of the FYE study along with this changing mathematical landscape in Ireland, provided the motivation for the development of the project-based learning (PBL) approach described in this paper. Coupled with this point, in the Technological University Dublin (TU Dublin), students are offered two main routes to obtain a Level 8 engineering qualification: via direct entry onto a 4-year honours degree programme (Level 8) or alternatively through a 3-year ordinary degree programme (Level 7) followed by a transfer into third year of the Honours degree (Carr *et al.*, 2013;). Therefore, this project is an attempt to evolve the teaching of engineering mathematics at Level 7 to both improve the engagement of students in engineering mathematics classes and to provide a deeper understanding of the material, which may ultimately help these students to progress onto a Level 8 degree. In particular, statistics is ready made for simple applications being introduced early on.

1.1 Aims and scope of the project

Within TU Dublin, we wish to move towards a more student-centred learning approach for the teaching of mathematics across all 3 years at Level 7. This approach has been piloted in the third year of the programme (Carr & Ni Fhloinn, 2016; Carr *et al.*, 2017) and was extremely successful both in terms of increasing engagement and covering a wide range of mathematical competencies. We are now working backwards to eventually integrate this approach into first year and this is our first attempt at introducing such an approach into the second year of the programme.

Much work has been done on using project-based/application-based learning as a method for teaching mathematics in higher education, but these modules have many mathematical prerequisites, so in the main they are only suitable for later years of a programme and/or are essentially being ‘bolted on’ (Young *et al.*, 2011) to pre-existing modules. Some work has been done in the third year of the Level 8 degree programme to teach mathematical modelling with good success (Keane *et al.*, 2008). If this approach is to work, it may be easier to introduce it in third year, then to second year and hopefully then to first year. The aim of this work is to use a ‘hybrid approach’ to ‘project-based-learning’ aligning to Gratchev & Jeng’s (2018) findings and consistent with previous work within the third year (Carr & Ni Fhloinn, 2016; Carr *et al.*, 2017) of this programme. This approach comprises of a significant amount of the prerequisites being taught over several weeks in a more standard approach followed by the introduction of a realistic project that consolidates the material that has been covered in class. It provides an opportunity to learn applications of the material (Carr & Ni Fhloinn, 2016). Many of these students will go directly into industry upon graduation but some will remain in academia and proceed to do a Level 8 course. We need to provide a level of training that will prepare them for industry but will also give the necessary mathematical background to proceed to an honours degree programme. We feel that the use of project-based learning is an ideal way of covering both eventualities.

Table 1. *Minimum recommended amount of mathematics per week for pupils in the Irish educational system (Department of Education and Skills, 2011b)*

School stage	Age	Mathematics hours per week
Infant (2 years)	4–6 years	3 h 25 min
Primary (6 years)	7–12 years	4 h 10 min
Secondary (5–6 years)	13–17/18 years	5× 35–45 min

The overall objectives of this project are to improve engagement and ultimately retention of students; to give students a deeper understanding of the material and a fuller range of mathematical competencies; to introduce problem-solving, teamwork and communication skills; to move towards a more student-centred environment within the existing structure of lectures and tutorials; to better prepare students for the workplace; and to create a series of problems that can be used by lecturers teaching on the early years of an engineering mathematics programme.

1.2 Irish education system and the teaching of mathematics

Irish children spend 8 years in primary school. Since 2011, approximately 4 h of mathematics are recommended per week; however, prior to that, approximately 3 h per week of mathematics were recommended (Department of Education and Skills, 2011a). Students transfer to secondary school at age 12, where they spend between 5 and 6 years in further education. Mathematics is compulsory for all years of secondary school with a recommendation of at least one mathematics class (usually 35–45 min) per day for all 5 compulsory years (Department of Education and Skills, 2011b). This is shown in Table 1.

Mathematics is not a compulsory subject in the final years of secondary school, but due to the matriculation requirements of higher education institutes virtually all students study mathematics. For example, in the 2015 state examinations, 97% of students sat the Leaving Certificate mathematics examination. Irish students receive an average of approximately 580 h mathematics tuition across their time in secondary education but there is a wide variation in total tuition time from school to school (Prendergast and O'Meara, 2016).

1.3 Project Maths: secondary level reformed curriculum in Ireland

To combat the 'Maths Problem' in Ireland, significant changes have been made to the second level mathematics curriculum with the introduction of 'Project Maths'. This reformed the curriculum placing greater emphasis on student understanding of mathematical concepts, enabling students to relate mathematics to everyday scenarios with an increased use of contexts and applications (Prendergast *et al.*, 2017). Project Maths also aims to promote further focus on problem-solving skills and the alignment of assessment with the aforementioned revised classroom practices. Project Maths consists of three main changes, namely what students learn in mathematics, how they learn it and how they will be assessed. The syllabi were rearranged and divided into five main strands (statistics and probability, geometry and trigonometry, number, algebra and functions and calculus). Changes began to be rolled out nationally on a phased basis in September 2010. Hence, students who had encountered Project Maths first entered third level education in September 2012. The phased implementation means that for each consecutive year after 2012, students have entered third level after being examined on more and more of the reformed syllabi. In 2014, students entering third level would have been examined on all five strands of Project Maths in their second level state examinations. Since 2018 we are seeing graduates from third level who have completed the entire reformed syllabus.

2. Method

According to Koparan & Güven (2014), in this current 'information era', data literacy has become an essential skill and highly relevant in the field of mathematics and science. This is also required in the field of engineering (Ben-Zvi & Garfield, 2008). Koparan & Güven (2014) investigated the use of PBL to help develop robust statistical literacy skills of their 8th grade students. Their findings were encouraging, showing that this approach not only helped their understanding on the subject matter but also, via the projects, promoted a cooperative working and learning environment for students. Given these positive results for 8th grade students and the success of previous work by Carr & Ni Fhlionn (2016) with third year Level 7 students, it was deemed appropriate to trial this with a second year Level 7 Automation Engineering student cohort, and in particular on the topic of statistics. The Automation Engineering programme involves the design, development and implementation of sensor and robotic systems for applications across a wide range of technological sectors according to the TU Dublin website (www.dit.ie). The students under investigation are in year 2 of a 3-year Level 7 degree. Typically there are approximately 30 in the class.

Aligning with the approach investigated by Gratchev & Jeng (2018) and applied by Carr & Ni Fhlionn (2016), a 'hybrid' approach of teaching statistics was used in this study. This involved introducing a significant quantity of fundamental statistical material and examples using the traditional teaching in-class approach and then introducing a realistic project to consolidate the theory discussed in class whilst providing the opportunity for students to learn how this is applied in real-world situations.

Improvements to teaching statistics such as providing 'authentic statistical experiences' (Bryce, 2005), along with the consensus that it is taught more effectively with real data (Cobb & Moore, 1997) and the increased benefit to students' learning if they collate their own data (Hogg, 1991) all influenced the design and delivery of the statistical projects taken in this study. Some research also suggested that personal relevance is important for successful learning (Mvududu, 2003). This was also factored into the project design.

Specifically in this study, there were a total of 23 students. The class is split into two groups A (11 students) and B (12 students). Groups A and B were timetabled for class on separate, alternate weeks. Randomly group A was divided into three teams (one team of three students and two teams with four students); group B had four teams, all with three students in each. The experiments were designed such that each probability distribution would be covered in each group. The experiments based on the normal distribution (Project 1 and 2, Table 2) were devised based on the lecturer's own personal industrial experience in developing control limits in high-volume manufacturing; albeit simplified and tailored to ensure students could achieve adequate data collation and perform basic analyses. The other distribution projects were based on aspects that might interest the cohort of students and provide an ability to gather the data within the project time constraint (2 h). The questions compiled for each project were similar to those exam type questions students would experience where the initial statistical data are already provided.

The objective of the statistical real-world projects was ultimately to give students a better understanding of the material but also to help further develop their problem-solving, teamwork and communication skills, linking to their other course module on communications where the emphasizes is strongly placed on the importance of these softer skills when applied to technical problems/situations in reality.

TABLE 2. *Overview of the 'Real-world' statistical problems*

#	Project topic	Brief description
1	High-volume production of mini-bars	High-volume production companies wanting to ensure products are in control based on either weight or length parameters. With a sample of production material, students would be asked to determine the probability of finding a bar of a certain weight/length based on their data.
2	High-volume production of tear drop metal components	
3	College soccer club 'Finger Footie' penalty shoot-out competition	Prize for team of students who score the most in five attempts. Project involved determining the best shooter strategy and students were asked to determine the probability of scoring a random amount of goals based on their selected strategy.
4	M&M's distribution	Identifying the proportion of each colour of M&M's in a random sample of fun size packets and determining the probability of finding any particular colour when randomly selected from a packet.
5	Student safety alert: addressing student jaywalking main road between college campuses	Garda Traffic Corp. has been receiving complaints from drivers regarding the dangerous behaviour of students crossing a main road and not using the pedestrian crossing provided. Students Union would like to see a safe footbridge constructed in a better location and also wanted to gather evidence of the issue raised. They want to be able to determine the probability of a student J-walking v's using the pedestrian crossing in any given 15-min period.
6	Student transportation—city bicycle availability	Addressing an issue raised by students due to the lack of availability of city bikes to support their requirement for them to attend lectures before and after lunchtime held on different city campuses. Students were asked to determine the probability that within any 15-min period during lunch at least four bikes would be available.

2.1 *Overview of the projects*

After completing three 2-h traditional classroom lectures on probability and various statistical distributions (normal, binomial and Poisson) the students were divided randomly into their teams at the start of the next 2-h session. The overall instructions and expectations were discussed by the lecturer. Identical concealed boxes, each containing a different project, were placed at the top of the classroom and one student from each team was asked to select a box and bring it back to their teammates where they opened the box containing the overall instructions, the specific project descriptions and basic tools required to collate the data i.e. a bag of mini-bars, weighing scales and callipers were placed in the project box relating to Project 1 (Table 2) along with the documentation mentioned above.

The students within each group were expected to read the project scenario and discuss it as a team to determine what data should be collated, divide out various tasks amongst themselves and start immediately on the project during the remainder of the session. This class time was supported by the lecturer to address any queries. It was also highlighted to students that some additional time outside of class may be required in order to complete it. The main focus of this first session was the collation and/or generation of data. Students were not told which distribution could be related to their project. The project topics are briefly outlined in Table 2. Specific questions were asked in each project scenario which the team also had to use their data to help answer and present. At the end of their 10-min presentation each group of students was asked another unseen question in which they had to use their analysed data on the spot in order to provide an answer.

TABLE 3. *SALG survey: generic structured headings*

1.	Your understanding of class content	The Learning
2.	Increases in your skills	
3.	Class impact on your attitudes	
4.	Integration of your learning	
5.	The Class Overall	The Process
6.	Class Activities	
7.	Assignments, graded activities and tests	
8.	Class Resources	The Support
9.	The information you were given	
10.	Support for you as an individual learner	

2.2 *Gaining student feedback: assessing the knowledge and learning gains*

Directly following the presentation session, students were asked individually to complete an online survey using the open source 'SALG' instrument to gain their feedback. The SALG is an online open source survey tool—**S**tudent **A**ssessment of their **L**earning **G**ains—https://salgsite.net/ used to measure students' learning gains. From the experience of previous work in creating a survey for this type of study (Carr *et al*., 2017) and feedback shared in presenting the findings, it was agreed that using this standard tool would be beneficial in understanding the impact of the project on student learning. It was also considered optimum to conduct the survey directly following the presentation session under supervision to help support participation and to clarify any questions students might have on the survey content.

2.3 *Overview of the survey questions*

This section outlines the survey questions edited specifically for this particular project but which follows the prescribed format designed to help assess learning gains. Results were anonymous and there is the ability to download comments and basic statistical analysis of responses. The structure of the standard survey remains consistent with 10 headings insofar as the general categories for assessing learning gains. The questions within each of these headings can be edited to suit the particular needs of the learning session i.e. the 'class' or in this case the 'statistics project'. Three to four questions were asked under each of the 10 headings captured in Table 3 and were edited slightly to suit this particular student exercise and learning experience. Some questions were open-ended providing the opportunity for students to expand on their feedback with the majority of questions asked via a Likert-type five-point scale, with 1 indicating 'no gains' in their learning to 5 indicating 'great gain' obtained from the particular learning.

It took students on average 10–15 min to complete the survey. In total there were 12 respondents, giving a 57% response rate. Full details of the actual survey used can be obtained on the SALG website searching for Instrument # 79785.

2.3.1 Results—observations of the students' reaction. There were five groups in total who participated (four groups of three and one with four students). This project was run in the past 2 weeks of the semester. Students were excited and intrigued with the introduction of the project and did appear to divide the work successfully amongst themselves. They quickly read the instruction sheet as to what had to be

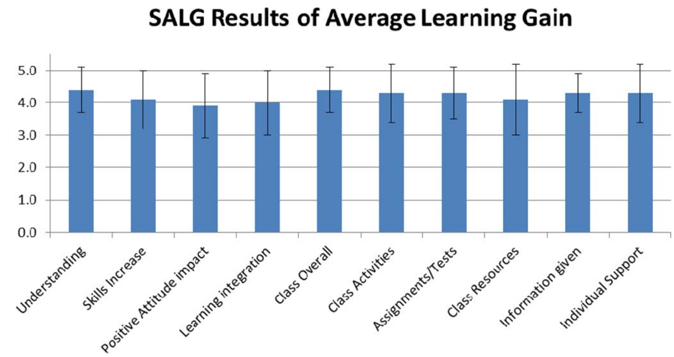

FIG. 1. Overall SALG survey results of average gain in each category (from 0 = no gain to 5 = great gain).

done and were more interested in reading the project scenario itself. Great effort and enjoyment was obvious in collating and generating their own data; however, many students struggled to identify what was the most appropriate distribution to apply to their type of data. Few consulted the class notes and the majority of students resorted to 'google-ing' the topic in order to find more information. Students did not automatically make a soft copy of their data that could be easily shared and analysed (for example using an MS excel spreadsheet where simple statistically analysis such as mean, min, max and standard deviation can all be determined with ease). Instead they manually recorded the data and then conducted the analysis using scientific calculators. In general, most teams were driven by one self-appointed individual determined to complete as much of the project in-class as possible. Some team members were absent for the second session on presenting the findings. This could be linked to the timing of the project and the workload of the programme at this stage (this presentation session was held in the last week of semester where the students also had a major team project to submit).

2.3.2 SALG survey results. Below is a synopsis of the survey responses under each theme. All results reported are on a five-point Likert scale, with 1 aligning to 'no gains' up to 5 aligning to 'great gains', and the students are self-assessing their learning gains. Given the methodology we use it is not possible to do a before and after comparison. There is a baseline instrument in SALG that allows for a self-assessment at the beginning of the semester and this is something to be considered for use in the future.

Results below contain the average score in brackets over the 12 respondents. Graphical representation is captured in Fig. 1.

2.3.4 Understanding class content. Students indicated they made good gains (4.4) in their understanding of the statistical concepts and good to great gains (4.6) in how studying this type of material would help people address real-world problems. When asked how their understanding of statistics has changed as a result of this project students positively responded that it made the importance of statistics and its use in the engineering discipline a lot clearer '*before this class I had no real understanding of statistics, so the resulting change would be 100%*'. From the way the class was taught students felt that using real comparisons/data helped them remember the key ideas that were presented '*clearly*' and were '*well explained*'. Using the data to answer additional questions also helped in remembering these key ideas.

2.3.5 Increases in skills and attitude. Students felt they had moderate good gains (4.1) in developing their skills in identifying patterns in data, analysing and presenting data and working effectively together. Some commented that their general skills on statistics improved echoing the response from the previous category in gaining better understanding of the subject matter. Overall, a positive attitude (3.9) towards statistics resulted through their increase interest and confidence in it with one student commenting that they '*always liked maths but just not the statistics section but after attending a class just specific to the subject, really helped me in changing my view and made me understand it which means I like it too*'. Notwithstanding this, however, many teams struggled at the start of the second 2-h session to pull the relevant information together in a brief presentation and found it difficult to use their analysed data to answer the questions on the project.

2.3.6 Integration of learning and overall impact of the project. Students were asked how they could use this project and apply it to other situations or in problem-solving. They all agreed it provided good gains (4.0) with some suggesting they could apply it to '*critical thinking*' or for '*designing automation projects*' and helped in understanding the value of data collection. In relation to the class overall, specifically focusing on the instructional approach taken the students positively responded (4.6) commenting that things were '*well explained*' and having the lecturer '*open to questions*' and '*repeated questions ... ensured all students were on the same page*'. The fact that work was '*evenly distributed*' amongst the team as the lecturer encouraged individuals by asking questions also appeared to have a positive impact. That said, however, students were '*indifferent*' as to whether the project changed the way in which they studied in general.

2.3.7 Class activities, assignments and tests. Students all agreed that attending and participating in lectures improved their learning (4.4) as well as doing the hands-on work on the project. Students commented on the fact that the class questions helped them learn with one student commenting that '*questions were asked that I didn't want to ask*' thus enhancing their learning. Students highlighted that this project positively required an extra mental stretch (4.4) that helped also in their learning.

2.3.8 Class resources, information and support. Additional to the class notes used in the traditional lecture sessions prior to the project, students were also provided with the Helping Engineers Learn Maths (HELM) online notes on statistics and probability. They were encouraged to use additional textbooks to help in their understanding. Whilst there was positive feedback on the use of the class notes themselves, little or moderate gains were obtained from standard textbooks on statistics according to the students. It is questionable how much time and effort students put into reviewing this additional material however. The teams were anxious to use the lecturer to assist them in answering these questions rather than take the time to review class notes or alternative resources offered to them. Interacting with the lecturer (4.5) and working with their peers in-class (4.3) proved to be most beneficial for the students in helping their learning of the subject matter overall as it '*gave us a chance to listen and learn off each other*'. A student commented that the pace of the project work was good, which helped their learning.

Overall, the results from the student survey were very positive and students seemed to agree that the practical real-world approach of the project work supported the in-class more traditional approach to the topic. However, very little can be concluded in how this project helped with the end-of-semester exam as only four students answered the question on statistics, three of which either did not participate at all in the project or only attended the first project data collection session.

During the presentation session students were asked on-the-spot questions relating to their work and to perform another calculation using their data. This was to try to capture what level of understanding and knowledge the students gained from their specific project. About 1/3 of teams were able to answer these questions satisfactorily whilst further discussion and clarification by the lecturer was required to help the other 2/3 of teams. The benefit was that ALL students were exposed to these presentations and question and answer sessions to reflect the potential benefits of peer-to-peer assisted learning as outlined by Boud (2001).

3. Findings and discussion

The feedback to this approach is very positive; we certainly see strong evidence of engagement and an increase in understanding. Previous work (Carr *et al.*, 2017) has shown that this approach works at least as well as the traditional approach in terms of answering traditional type questions, but in addition, there is an increase in other skills such as problem-solving, team work and application of mathematics to the real world. Given that this is just a provisional study we have enough positive findings to justify a more rigorous analysis of this approach next year. In addition, it does show that this PBL approach can be introduced in second year and probably into first year of the programme.

However, it was difficult to specifically quantify the overall knowledge gain explicitly albeit the survey attempts to provide this. The test for the level of actual knowledge gain was to be reflected in the ability and quantity of students taking the terminal exam question. In reality, this did not occur during this particular study with only four students taking the statistics question during the end of term exam, only one of whom had actually participated in the projects. This might have been due to the quantity of choice students were presented with in the terminal exam (choice of 8, answer 5) or the level of confidence in taking the question.

4. Future work

Firstly, the timing of delivery of this class exercise was rather late in the semester and may have had an impact on participation and student focus. Secondly, we need to do a more rigorous quantitative analysis of knowledge and learning gains. This will include the sourcing of a suitable statistical competency test. The SALG instrument also has a baseline test that can be given early in the semester. Again this is a self-assessment tool but it does allow us to estimate where the students are at relative to the course objectives. Finally, given that this topic was given late in the semester many of the students did not answer the exam question so it is difficult to get information comparing exam performance with the project performance. In future we will move to having all questions compulsory on the final exam (Carr *et al.*, 2008). Probably including a specific question on the survey to see if they feel this prepares them for the final exam would be of benefit.

This approach has been used extensively in third year for the teaching of both first and second orders differential equations (Carr *et al.*, 2017). The longer-term plan is to move to teach as many topics as possible in the second year of the programme using this approach and ultimately introduce this approach to first year engineering mathematics.

References

[1] Ben-Zvi, D. & Garfield, J. (2008) Introducing the emerging discipline of statistics education. *Sch. Sci. Math.*, 108, 355–361.

[2] Boud, D. (2001) Making the move to peer learning. *Peer Learning in Higher Education: Learning from and with Each Other* (D. Boud, R. Cohen & J. Sampson eds). London: Routledge, pp. 1–20.

[3] Bryce, G. R. (2005) Developing tomorrow's statistician. *J. Stat. Educ.*, 13.

[4] Carr, M., Farrell, F. & Ni Fhloinn, E. (2017) A project-based-learning approach to teaching first-order and second order differential equations to engineers. *SEFI 2017 Annual Conference, 18–21 Sept 2017*. Brussels: SEFI.

[5] Carr, M. & Ní Fhloinn, E. (2016) A project based-learning approach to teaching second-order differential equations to engineers. *18th SEFI-MWG European Seminar on Mathematics in Engineering Education*. Brussels: SEFI.

[6] Carr, M., Ní Fhloinn, E., Murphy, E. & Bowe, B. (2013) Addressing continuing mathematical deficiencies with advanced mathematical diagnostic testing. *Teach. Math. Appl.*, 32, 66–75.

[7] Carr, M., Shiels, D. & Ní Fhloinn, E. (2008) Reducing choice = increasing learning or decreasing marks? *MEE 2008: 14th SEFI(MWG)/IMA Conference on Mathematical Education of Engineers*. Brussells: SEFI.

[8] Cobb, G. W. & Moore, D. (1997) Mathematics, statistics, and teaching. *Am. Math. Month.*, 104, 801–823.

[9] Cusack, T., Gilmartin, M., Roper, R., Carr, M. & Freeney, Y. (2013) An examination of the coherence between the National Educational Strategy in Ireland and the results of a study examining the first year student experience. *SRHE*. London: SRHE.

[10] Department of Education and Skills (2011a) Initial steps in the implementation of the national literacy and numeracy strategy. Circular letter, 0056/2011. http://www.education.ie/en/Circulars-and-Forms/Active-Circulars/cl0056_2011.pdf.

[11] Department of Education and Skills (2011b) Revised syllabuses in junior certificate and leaving certificate mathematics for leaving certificate examination in 2013 and junior certificate examination in 2014. Circular letter, 0058/2011. http://www.education.ie/en/Circulars-and-Forms/Active-Circulars/cl0058_2011.pdf.

[12] Gratchev, I. & Jeng, D.-S. (2018) Introducing a project-based assignment in a traditionally taught engineering course. *Eur. J. Eng. Ed.* 43.

[13] Hogg, R. V. (1991) Statistical education: improvements are badly needed. *Am. Stat.*, 45, 342–343.

[14] Jeffes, J., Jones, E., Wilson, M., Lamont, E., Straw, S., Wheater, R. & Dawson, A. (2013). Research into the impact of Project Maths on student achievement, learning and motivation: final report. Slough: NFER.

[15] Kaur, B. (2010) Towards excellence in mathematics education—Singapore's experience. *Procedia Soc. Behav. Sci.*, 8, 2010, 28–34.

[16] Keane G., Carr, M. & Carroll, P. (2008) An integrated approach to the teaching of numerical methods to engineering students. *Proceedings of INTED*. Valencia: IATED.

[17] Koparan, T. & Güven, B. (2014) The effect of project based learning on the statistical literacy levels of student 8th grade. *Eur. J. Eng. Ed.*, 3, 145–157.

[18] Mvududu, N. (2003) A cross-cultural study of the connection between students' attitudes toward statistics and the use of constructivist strategies in the course. *J. Stat. Educ.*, 11.

[19] Prendergast, M., Faulkner, F., Breen, C. & Carr, M. (2017) Mind the gap: an initial analysis of the transition of a second level curriculum reform to higher education. *Teach. Math. Appl.* 36, 217-231.

[20] Prendergast, M. & O'Meara, N. (2016) Assigning mathematics instruction time in secondary schools: what are the influential factors? *Internat. J. Math. Ed. Sci. Tech.*, 47, 1137–1155.

[21] Roper, R., Carr, M., Cusack, T., Gilmartin, M., & Freeney, Y. (2013) Interventions that enhance the first year experience: a systematic review of the literature. *European First Year Experience*. Bergen: EYFE.

[22] Yates, P. (2003) *Teaching mathematics to first year undergraduate chemists in the context of their discipline*. Maths for Engineering and Science LTSN MathsTEAM booklet. York: HEA.

[23] Young, C. Y., Georgiopoulos, M., Hagen, S. C., Geiger, C. L., Dagley-Falls, M. A., Islas, A. L., Ramsey, P. J., Lancey, P. M., Straney, R. A., Forde, D. S. & Bradbury, E. E. (2011) Improving student learning in calculus through applications. *Internat. J. Math. Ed. Sci. Tech.*, 42, 591–604.

Fionnuala Farrell is a chartered engineer lecturing in the School of Mechanical and Design Engineering in the Technological University of Dublin. Applying her industrial experience as an expert engineer, her interests include the use of project-based learning in teaching statistics to engineers as well as supporting community-based team projects to develop new products. She has researched in the area of providing effective student feedback and is currently investigating the use of a blended learning approach in teaching core professional skills to student engineers as well as in more technical subjects such as innovation management and sustainable manufacturing.

Michael Carr is a senior lecturer in mathematics and statistics in the College of Engineering and Built Environment in the Technological University of Dublin. His research interests include the first year experience of students, development of core mathematical skills in university students, mathematics education for engineers and maths education in prisons.