From 'Blind Drawing' to How to Make a Cheese and Vegemite Sandwich: Motivative Teaching Elements to Foster Connections

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Abstract

Whilst student engagement when teaching STEM subjects is critical, it is often hampered by student anxieties and a general lack of connection and context. This paper incorporates a collection of STEM-related case studies from courses independently constructed and delivered at the University of Newcastle, Australia. These case studies highlight the breaking down of the instructor-student barrier by means of personal or historical storytelling, icebreaking activities, project-based learning, and gamification. Through the application of these principles, we have observed improved student outcomes as measured numerically through Quality Learning Experience scores, as well as directly via positive student feedback. Furthermore, upon collective examination of the case studies, a base set of best teaching practises can indeed be employed across the STEM disciplines to foster engagement.

Introduction

Establishing a personal connection with an audience is a perennial problem for instructors, but one crucial to success in the classroom. Strong relationships between student and teacher are associated with both short- and long-term improvements to a range of student outcomes (motivation, engagement, achievement, retention, and well-being) (Hagenauer, Muehlbacher & Ivanova, 2023; Kahu & Picton, 2019). Accordingly, a variety of pedagogical techniques to establish such a connection have been developed and refined, but this then begs an obvious question: can all of these techniques be applied equally to any course? For example, McComas (2017) notes an increasing homogenisation in teaching practises for STEM subjects, with any differences between the disciplines being minimised or even ignored. Any examination of best teaching practises for STEM must then closely examine whether it is better to adopt a similar instructional approach across the entire field, i.e. Should instructors *collectively* use the same techniques regardless of discipline, or do courses require *distinct* pedagogical approaches to each discipline? In this work STEM refers specifically to the disciplines of Science, Technology, Engineering and Mathematics, noting that Science includes Physics, Chemistry, and Biology, but not the Social Sciences. The amount of overlap between these disciplines will vary, but all share the common aspects of problem solving, critical thinking, and innovation. Science and Mathematics typically involves fundamental concepts that give foundation to the applied disciplines of Engineering (design- and build-oriented) and Technology (computers and information).

The methods available to foster connections to students are many, but to simplify the following discussions we will attempt to highlight a few broad categories. With respect to gaining student attention and interest towards the beginning of a course, one can engage students in a memorable fashion with large or particularly exciting demonstrations (Wieman & Perkins, 2005). Such lecture 'performances' often incorporate historical storytelling to connect directly with students (Hadzigeorgiou, 2006) and have been shown to generate anticipation and curiosity to provoke and assist learning outcomes (Stinner, 1995; Egan, 2005). The mandated pedagogical approach at the heart of teaching and learning at the University of Newcastle is the connection to students through the 'stories we share' (8ways, 2011). Further to the use of storytelling as a powerful tool to teach and inspire, the use of personal anecdotes and often humour have also been demonstrated to be an excellent means to create a sense of connection and break down the barrier between student and instructor.

A cornerstone for STEM-based learning, students learn through participation, examination, and finally articulation of their discoveries (Astuti, Rusilowati & Subali, 2021). Course activities provide both the instructor and student with feedback about the individual's progress at important interstitial stages in the process (Cowley, Heikura, & Ravaja, 2013), a method referred to as 'reinforced feedback'. Not all students possess the confidence to fully participate in said activities, especially when they are the basis for an assessment task. Shekhar et al. (2020) studied active learning in STEM classrooms and found several main negative student responses, of which lack of confidence was one. Icebreakers by definition relieve inhibition or tension between people (Cambridge. (n.d.)) and are recognised as being essential in building a positive and productive learning environment (Mepieza, 2023). Icebreakers come in a variety of shapes and sizes but rely on invoking laughter, play, and playful experiments with no assessment ramifications. Studies have found that the use of well-considered icebreakers closely correlates with elevated engagement by increasing students' attention and helps foster a sense of community (Dixon, et al., 2006; Kahu, 2023).

More recent additions to the toolbox with STEM include 'Game-Based Learning' (GBL) and/or 'gamification', as well as 'Project-Based Learning' (PBL). PBL involves students undertaking a central project under the mentorship of the instructor to develop the necessary critical thinking. Beyond the oft cited problem solving and self-directed learning skills, PBL has shown evidenced success for enhancing students' communication and interpersonal skills (Owens & Hite, 2022). Gamification of learning methods have had mixed impacts on student STEM engagement (Ortiz, Chiluiza & Valcke, 2016), with maximum learning generally coming through directed and specific gamification, rather than attempting to employ the idea broadly. As such, gamified learning should be approached as a valuable complement to other forms of learning, rather than a replacement.

The current work centres around a collection of case studies that employ interactive examples of establishing a positive connection to students, targeted to up-and-coming lecturers. The case studies include STEM courses utilising a blended and multimodal pedagogy to maximise learning (Gladys et al., 2022), which include a scaffolded inquiry-based instruction containing implicit structures to engage students to think and act like scientists (Crippen & Archambault, 2012). The courses were each developed and delivered separately at the University of Newcastle, but all involve the enhanced pedagogical techniques discussed above in some fashion. Based on these independent-written case studies, the authors are thus attempting to answer the question:

'Should we instruct STEM courses in a collective or distinctive way to create a positive connection to students?'

Case Study 1: Sport Science

Society portrays 'jocks' and 'nerds' with two very different personalities (Mann, 2017), with these and other slang words tending to be masculine, derogatory and – by their very use – non-inclusive. Kanniyan, George, and Valiyakath (2015) found significant differences between male athletes and non-athletes, whilst other studies similarly discovered significant differences in personality traits between female athletes and non-athletes (Burdzicka-Wołowik & Góral-Radziszewska, 2014).

From conversations with students in the HUBS2105 second year Sports Science course at the University of Newcastle, those who hadn't studied Physics previously struggled to grasp the material and find motivation to study for the topic as they couldn't comprehend the relevance to their chosen field of study. This lack of perceived relevancy stemmed mainly from recollections from their own high school experiences but also from a place of fear of not understanding the material. The course covered two areas: Biology and Physics. The Physics topics involved mechanics and biomechanics, with examples having direct relevance to sports as covered in the high school curriculum in Personal Development, Health and Physical Education (PDHPE). The curriculum included the fundamentals of scientific notation and vectors, through to forces (including friction), projectile motion (1D and 2D), energy and work, rotation and finally a qualitative look at the influence of air resistance. The course was set out with 2-hour 'lectorials' (a hybrid of lecture and tutorial) each week and six 2-hour laboratories (Gladys et al. 2022).

One method that notably increased student participation and ownership of their learning was to ask the students how they were going to connect with the students that they will teach in the very near future. The student-led discussion centred around utilising their own experiences and achievements in different sports. After some time, the lecturer shared an anecdote:

"When I found out I was taking over this class, my first question to myself was, how am I going to connect with physical education students. I am not athletic, I used to play sport, but I am more of a geek who loves sci-fi and fantasy. So, I decided to participate in all the lab activities."

He then asked the cohort: *"How are you going to connect to the 'geeks' and 'nerds' when you're teaching PDHPE? Further, how are you going to connect to academic-type students when faced with teaching in science or any other class you must fill in for?"*

The instructor then added: *"I am asking these important questions because you may well be teaching my kids in the near future, and as a parent I want to know that they are getting a good education."*

Stunned silence was the answer. *"The best way to connect is to get on their level. This course is giving you the background in Math and Science to inspire the academic students."*

The attendance and participation levels in the lectorials substantially increased (by up to 20%), with historically less-confident students beginning to ask questions, and, more generally, students reviewing the course material prior to coming to class. Part of this outcome may have simply come from establishing an honest rapport with the students. Whether it's wanting the students to do their best, or giving students the best potential to succeed, honesty is one of the most human connections there can be between a student and instructor.

Additionally, the lecture slideshow materials, files, and demonstration videos were designed so that the students could directly use the material for their own teaching purposes. The audio included the instructor incorporating historical stories to help relate to the dry equations in mechanics (Hadzigeorgiou, 1999). Overall, the material was targeted to explore and understand real-world sporting activities such as the PBL scenarios outlined in more detail in subsequent sections of this paper. Historical stories for all topics have been used in every first year Physics course, including PHYS1205 (Fundamentals of Engineering Physics), but were tailored for the individual cohort; similarly, Civil Engineering and Surveying students received construction-type anecdotes. The Sports Science course included stories ranging from the first description of human movement by Leonardo da Vinci (Codex Atlanticus, n.d.), through to modern interpretations such as “Bend it like Beckham” (Goff & Carr 2009), or even humorous asides like “Doing a Bradbury” at the Winter Olympics (Olympics, n.d.). The incorporation of storytelling in all of its forms allowed students to connect with the context of the material and enable superior learning outcomes.

Case Study 2: Coding Technology

The teaching and learning of good coding practice is an inherently challenging process as it includes the comprehension of abstract concepts and pseudocode, an understanding of complex syntax, the design and development of problem-solving algorithms, as well as sequential thinking (Kandemir, Kalelioğlu & Gülbahar, 2020; Bashir & Hoque, 2016). Dewsbury and Brame (2019) stated that:

“To ensure a positive and inclusive coding experience, students must go through the following self-efficacy phases.

> *1. Find confidence to engage with instructor and peers and then,*
> *2. Practice until the confidence in their own ability is evident.”*

Unfortunately, many students enter post-secondary education with preconceived notions about programming and their own ability to code. As such, students commonly have no idea as to what is expected of them in an introductory programming course. Moreover, students will frequently struggle with what has been termed ‘computational thinking’ (CT) (Resnick, 2007), often due to misconceptions about what computers are – and are not! – capable of. Although the majority will have had at least some exposure to coding at school, in the author’s experiences this prior learning was without the necessary context to develop a deep understanding of programming fundamentals.

Engineering Computations and Procedural Programming (EPFNEG103) is a first-year course offered in the Diploma of Engineering program at the University of Newcastle. A rewrite of the original course placed heavy emphasis on the ‘why we code’ (that is, context) though practical, interactive demonstrations utilising PBL. The ‘how to code’ thus became a lot more interesting to the students, as evidenced by the improved in-class participation, performance and student feedback discussed below. In the revised version, the instructor and students together as a class solve relevant real-world problems, such as using GPS data to find the area and perimeter of the University of Newcastle’s Callaghan campus. This type of PBL was found to increase student motivation by contextualising abstract concepts, allowing the students to develop strong CT skills.

The first practical demonstration used in the lectorials was inspired by a Scientific American article “Robot, make me a sandwich!” (Science Buddies & Ben Finio, 2018) where groups of students are tasked with writing a ‘how to’ guide for making a cheese and Vegemite sandwich. Once the students had prepared their instruction list, the ‘robot’ (instructor) pulled out the physical ingredients and a chopping board, much to the surprise of the cohort. The robot then followed their instructions to the letter, leading to many laughs and some truly awful sandwiches.

The use of this humorous icebreaker allowed for the effective transmission of some fundamental truths about coding: computers are very literal devices, and garbage in will always lead to garbage out. When experiencing the positive effects of such an icebreaker, Fredrickson (2001) proposed individuals' thinking becomes "*more creative, integrative, flexible and open to information*". Further context was integrated into the course by sharing stories concerning the history of coding and why some aspects are the way they are. The historical focus on 'why we code' deemphasises syntax and semantics, underscoring the often forgotten highly creative nature of programming. Sharing photos and stories about real-world projects in which the instructor has been involved further contributes to the human touch required in teaching STEM (Roja-Suarez, Pérez & Vergel-Ortega, 2020; Hansson, Arvidsson, Heering, & Pendrill, 2019).

The redesign of the course took the mean Quality Learning Experience (QLE) score from 3.6 to 4.7 out of 5, where the university mean is 4.2. The participation rate for the student evaluation increased from 23% to 46%, reflective of the increased participation observed within the course. Prior to the redesign the feedback from students who did not enjoy the course centred around the category 'criteria' as shown in Figure 1. In other words, the students were unable to conceptualise how coding fit into their Engineering journey and thus struggled to learn such decontextualised material. The student responses to the humanisation efforts were positive:

"very engaging, with the use of real life examples making the questions feel more sensible"

"just being able to understand a new concept through repetition and practice. The overall structure of the course was fun and easy to follow and provided confidence in my ability to create code in python"

"Heavily interactive – challenging in a way that became very rewarding"

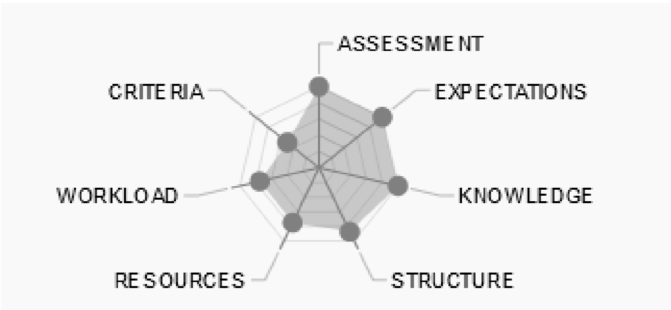

Figure 1: Spider chart showing student feedback for the original (pre-redesign) course for a range of categories. Centre is zero, outer ring is five.

Case Study 3: Engineering Design

Arguably critical to all of the STEM disciplines is the ability to express complex ideas clearly and unambiguously. Introduction to Mechanical Engineering Design (FNEG1110) is a course which centres on 'communication through technical sketching', requiring students to buy into to the idea that sketching comprises a common language among not only engineers, but also mathematicians, scientists, and many other professionals. Many students experience a significant barrier to entry with regard to the topic as they are inexperienced with what professional communication involves and often believe that they do not have the necessary drawing skills. As such, gamification was employed to both overcome the anxiety around their (self-assumed) sketching inabilities and to foster a collegial and inclusive environment where they could practise the communication skills being developed.

The game developed for FNEG1110 occurred in the first lectorial and acted as an icebreaker between the members of the student cohort, as well as with the instructor. A series of geometrically complex but familiar household objects (e.g. a stapler, wrench, whisk, etc) were placed in boxes out of view of the class. A volunteer was asked to observe the object in secret – developing intrigue and anticipation in the other students – before being tasked with trying to communicate said object verbally by describing the geometry. The most common immediate response from students was to start to use their hands to map out features, at which point the instructor was able to interject and comment on the fact that their inherent response to the task was to sketch out the object (in mid-air). Based on the descriptions of the volunteer, the rest of the class was tasked with sketching the described object whilst the instructor walked around and interacted with the attempts in progress. The instructor would call out the specifics of the sketches to bring attention to the wide variety of interpretations that arise due to the ambiguous nature of the description. This feedback was looped back to the volunteer at the front who would then typically try to refine their explanation as they observed how their previous depictions were being misconstrued. Feedback loops are important for games to be engaging and fun, but are also important in PBL with the intention to provide the 'player' information on the impact of their actions (Kearney, Pivec & Joanneum, 2007; Cowley et al., 2013).

Inevitably the quality and diversity of the resulting sketches provide opportunities for positive humour from the instructor and between students, allowing personal interactions to easily be made under the cover of a common goal. Martin (2002) explains that embracing a playful attitude, and particularly the use of humour, often counteracts the stressful experience post-secondary education can have on students as they learn to process new material. In the game the actual object was eventually revealed, at which point the instructor would be able to engage with reinforced feedback to comment on the difficulty in reaching agreement based purely on verbal descriptions. Indeed, the students have a greater chance of absorbing the information effectively when there is human interaction included from the instructor (Petro, 2016). The increased socialisation fostered by participation in several rounds of the game appeared to decrease anxiety and build confidence amongst the student body, as directly shown in the student feedback:

"Very fun and taught in an environment that allows students to understand, learn and ask questions."

"...feel confident [about] being able to make some quality polished work..."

Feedback on the course produced a mean QLE score of 4.5 ± 0.3 over a three-year period. Figure 2 highlights the spider chart from one of the students that only rated the course 'satisfactory', and yet gave 5 out of 5 for all categories. The following student comments relayed the sentiment for the course:

"A practical skill-based learning program"

"Taught everything very well and allowed room for questions. Gave the students time to understand the learning and to practice it."

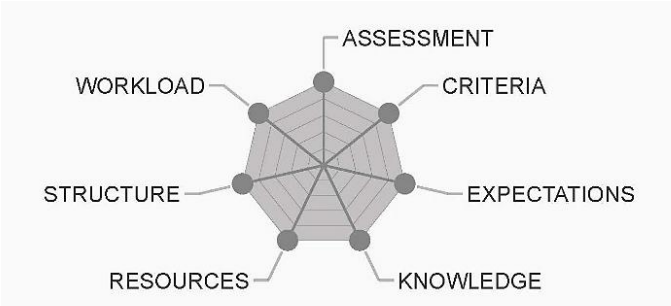

Figure 2: Spider chart for FNEG1110 2021.

Case Study 4: Engineering Problem Solving

EPENGG101 was an Introduction to Engineering Practice course in the Open Foundation program at the University of Newcastle. It was designed as a gentle, low-maths introduction to Engineering for students who were just dipping their toes into the educational waters. For some, attendance in the course constituted their return to formalised education, often associated with trepidation and angst; henceforth referred to as 'academic pause anxiety'. A typical cohort of students would have a wide range of backgrounds and abilities, often possessing a high degree of anxiety about re-entering a learning environment as many had poor previous experiences at school. Such a cohort presents a unique problem for an instructor, as the natural barrier between teacher and student is even greater in this case. Therefore, it was imperative to break down this barrier early on in the course.

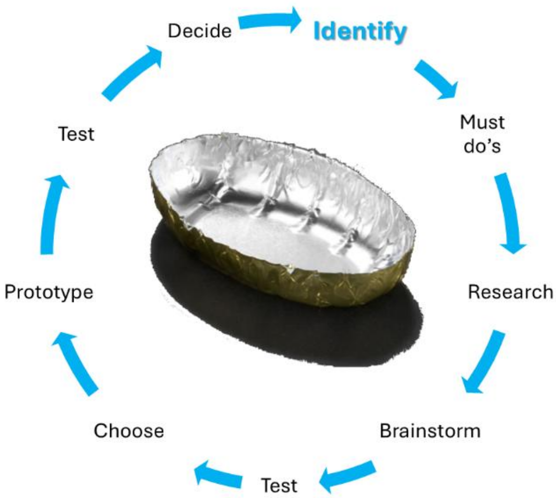

Figure 3: One variation of the Engineering problem solving cycle. The term 'Identify' highlights the natural starting point for the cycle.

The fundamental core to the entire EPENGG101 course was the engineering problem solving cycle, as shown in Figure 3. The cycle is a systematic approach that engineers use to tackle real-world problems and to design effective solutions (Koellner et al., 2007). Its importance was conveyed through historical storytelling, serving dual purpose as an icebreaker between the students and instructor. The instructor would begin the session by describing a storyline from the TV series 'Outlander', where the main characters are travelling by ship in the 1800s. The vessel encounters a large storm and is sunk. It should be noted that the recounting of this story was the first interaction between instructor and students, and its performative nature was designed to take them off guard and hence raise curiosity. At this point the instructor would ‘identify’ the advances in design that now allows ships to weather the type of storm that destroyed vessels of the previous era. The instructor would invite the students to form groups of four to build a boat from aluminium foil that had a payload of 5-cent coins. The requirement specification (the ‘must do’s’) for the boat was that it would need to survive ‘rough seas’ for at least ten seconds. The ‘ocean’ was a plastic tub filled with water and shaken by the instructor to simulate a storm. Firstly, groups had to create a sketch of their design and present it to the instructor to procure their sheet of aluminium foil. Many creative and non-seaworthy designs were built, with the doomed vessels causing much hilarity as they sunk to the bitter depths. The groups then received another opportunity to refine their boat designs taking into consideration what had happened on their first attempt; a second pass through the design cycle. Further soaking of the instructor then ensued as they rocked the water tub back and forward, along with significantly more seaworthy boats.

The instructor would then formally introduce the course and its goals, namely the engineering problem solving cycle in the context of the boat building exercise just completed. Each step of the cycle was equated to one part of the activity, making it straightforward for the students to understand a complex concept. This approach of introducing a concept with a light-hearted, fun group activity set the desired tone in the relationship dynamic between the lecturer and the cohort. A high level of student engagement, as measured by questions asked during the lectures, was engendered after the clearly memorable boat building session. Course feedback also supported this approach:

“I really enjoyed the practical tasks such as the foil boat making as it allowed the subject to be fun whilst allowing a teamwork focus in on a problem to be solved!”

The course regularly incorporated PBL tasks, including a group-based assignment asking them to research modern problems of national significance, such as those designated by the Trailblazer Universities Program (Australian Government Department of Education, 2022), or the Science and Research Priorities of Australia (Department of Industry, Science and Resources, 2015). As part of this assignment, students would investigate an issue discussed within these programs, pitching their idea for a new company that could solve a problem in their topic space. By choosing modern national programs as the foundation, the assignments were topical and relevant. To assist with this activity, lectorial time was dedicated to explicitly discussing the dynamics of group work and how to maximise output.

The course consistently achieved a mean QLE score of 4.2 out of 5, peaking at 4.8 in 2021; a university-designated rating of ‘good-to-excellent’. More importantly, the course established a bridge between students that were looking to resume academic study, and university culture. The prospect of going from dormant academic activity to the level required of a university course is quite daunting, invoking academic pause anxiety. The EPENGG101 course sought to steadily guide the student from the level they were at, to one consistent with the workload expected at the tertiary level. Establishing a meaningful connection between the instructor and students using icebreakers and PBL tasks was critical to the success of the course. By exposing the cohort to a multitude of different problems, it is hoped that the humanisation efforts encouraged them to embark on a lifelong journey of curiosity whilst finding enjoyment in the work along the way.

Case Study 5: Mathematics

5.1 Main problems in teaching maths: maths anxiety and class engagement

Mathematics (maths) anxiety refers to the feelings of fear and apprehension that many people experience when dealing with maths (Hunt & Maloney, 2022). There is a general feeling in Australian society that maths is a hard subject to learn and this stereotype can also contribute to 'maths anxiety' (Barroso et al., 2021). Maths anxiety is manifested in an avoidance of maths and feelings of helplessness when confronted with assessments. Confusion at different teaching methods and testing at high school and tertiary education seem to add to the stress around the subject, especially for first year students. From our experience, supported by other researchers (Hunt & Maloney, 2022), initially maths anxiety is not at all linked to intelligence or ability to solve the problem, rather it is more connected to student confidence. However, at subsequent stages of education, students' poor maths achievement can lead to increased maths anxiety again and again. Correspondingly, over the years the snowball effect of poor performance and higher maths anxiety develops. Girls and women are more commonly affected by this phenomenon (DiStefano et al. 2023). Maths anxiety (and more broadly confidence with respect to STEM learning) usually develops because of poor experiences at the school level, which leads to negative thought patterns about their potential at university.

5.2 Methods to beat the maths anxiety and increase engagement.

Motivation and engagement of students throughout university-level Mathematics courses is an enduring problem world-wide. Creating positive learning environments and motivating students to study maths in a playful way are powerful methods to humanise an often intimidating subject area. Injecting humour into the lectures and tutorials assists in dealing with anxiety and stress reduction (Rao & Stupans, 2012). These positive outcomes are reflected in both the QLE scores (average of 4.1 across the courses) and the feedback received from students:

"SFT 2017 MATH1110: Elena has made it easy getting up with a spring in each step for an 8am/9am Math lecture. Lectures are quite entertaining her slight injection of humour goes a long way. Big shoes to fill for our next lecturer."

"2022 MATH2310: Lecturer humour and eccentric quirks spice up what can be boring and dry subject matter…"

"2020 MATH1002: …snippers (sic) of humour, idioms or saying keeps the us engaged to the content…"

To keep students motivated and engaged, historical storytelling (such as the biography of a famous physicist or mathematician), or anecdotes based on the instructor's own experiences, is an excellent approach. Employing the latest research results as examples in teaching (Bubou, Offor, & Bappa, 2016) keeps students engaged in the coursework and increases intrinsic motivation; a driving force for deeper and life-long learning. For example, students typically appreciate when traditionally dry topics (such as the Laplace transform, Navier-Stokes equations, Monte Carlo method or covariance) are supplemented with real applications originating from the instructor's recent research.

PBL is a proven pedagogical tool that narrows the gap between the present mathematical education of engineers and expectations of their roles in the workforce. However, implementing PBL correctly in maths classes is a challenging task, as the real-world problems are often open-ended, interdisciplinary, and complex. To overcome this challenge we developed an innovative, integrated, and targeted approach that promotes student development by stimulating curiosity and independence in learning, as well as encouraging student engagement. The approach consists of two stages: segmentation of the complex problem, and attacking each segment via a targeted block of knowledge (see Figure 4). Each block of knowledge is delivered via a short, structured instructive guide, where the theory and real-world practice are integrated. This integrated and targeted approach revolves around student-centred education and synergistically utilises the following educational techniques and methods: reflection, differential teaching and learning, flipped classroom technique, research informed teaching method, group work and blended technology.

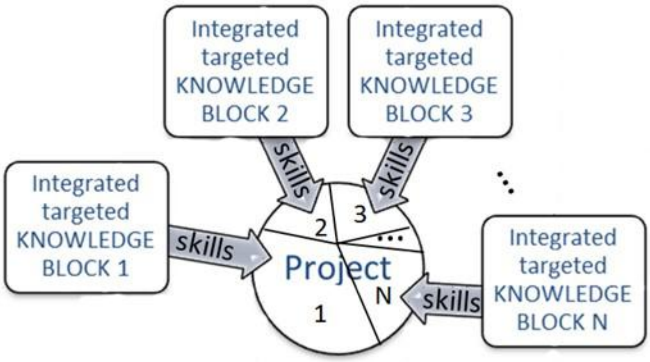

Figure 4: Targeted project base learning approach for maths-based courses

Since 2012 the Mathematics tutorials and workshops at the University of Newcastle have been conducted using 'Whiteboard Stand-Up Style Workshops' as described by Seaton et al. (2014). This method has not only improved student satisfaction ratings of the maths courses, but also improved learning outcomes. Indeed, Whiteboard Stand-Up Style Workshops encourage human interaction via peer-peer learning, group work and communication. Additionally, there are marked benefits to students from all background levels; that is, higher-level students learn by teaching lower-level students, cultivating communication and interpersonal skills.

Discussion and Conclusions

The above case studies, independently written by instructors at the University of Newcastle, discuss five autonomously developed courses across multiple STEM disciplines. The courses incorporate pedagogical techniques that not only increase student engagement and participation, but are personalised to establish meaningful connections between instructor and student. These connections were at the heart of the success of the courses and critical in maximising student achievement across the cohort. Comparing and contrasting the pedagogical techniques employed in their delivery, it is clear there is more in common than in opposition. First and foremost, despite the broad range of STEM subjects, the most common problem faced by instructors was students encountering mental barriers that have to be overcome before participating fully in the coursework (with examples including maths anxiety, social anxiety, and academic-pause anxiety). Whether occurring due to an unjustified, perceived lack of ability or necessary skills, historical stereotypes, or simply fear of the unknown, left untreated this obstacle will generally snowball towards negative outcomes. In particular, the historical stereotypes working against minority groups within STEM education reinforces the need to be particularly mindful of diversity, equity, and inclusion with regard to communication methods (Mepieza, 2023).

Surmounting these barriers requires the instructor being visible and present in their role as a facilitator of discourse and co-creator of a social environment. In forging a strong connection with the student cohort and the content being delivered, we see that a common thread across these courses is storytelling in both the personal and/or historical forms. The use of stories is particularly proficient in allowing people to relate to others and absorb viewpoints other than their own. As stated by Woodhouse (2011): *"... storytelling is to 'humanize' the process of learning by appealing to the students' imagination, so that they can consider themselves active participants in the pursuit of knowledge ..."*. This sentiment helps to explain why historical storytelling and personal anecdotes concerning the instructor's own experiences are so useful in creating an engaging environment and offsetting a degree of the inherent stress associated with learning. It is also clear from a comparison of the case studies that some form of icebreaker, preferably as early in the relationship as possible, is essential to break down the student-instructor barrier and facilitate better communication. The precise nature of the icebreaker – whether it be storytelling, a memorable performance, a game, or something else entirely – needs to be purposefully tailored to root it both in the course content, as well as in the style of the instructor.

Of interest to the authors was the ubiquity of PBL across the different STEM disciplines. As noted within the case studies, the specific nature of the group problem assigned to students to work through is a challenging exercise to develop and must be approached with caution. However, the benefits (enhanced communication between instructor and students, as well as between students) are clearly considerable enough to be worth pursuing. Beyond communication, the ability for PBL to anchor students in real world issues and provide the context for the course material should be considered core to enhancing their confidence. While PBL saw extensive use, gamification was only observed in a single case study, and in that particular circumstance functioned as a valuable icebreaker with the student cohort. Whilst effective when deployed specifically and selectively, it is perhaps not as universally applicable as some of the other techniques which may contribute towards some of the mixed results it has seen in the literature (Ortiz, Chiluiza & Valcke, 2016).

Now, let's return to our initial question: 'Should we instruct STEM courses in a collective or distinctive way to create a positive connection to students?' Based on the experiences embodied in these case studies, with respect to establishing effective communication it appears that the *collective* philosophy is indeed valid. The overlap between the various disciplines appear significant enough that the majority of the same pedagogical techniques to break down student-instructor barriers are effective. There will always be specific instances within any topic that must be directly catered to; however, a base set of best practices can be employed to create an atmosphere conducive to learning. For example, one cannot simply take a Mathematics PBL task and apply it within an Engineering course. It is incumbent upon those developing and/or delivering the material to ensure that the techniques in question are adapted to the course and cohort at hand.

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