Learning to Test With Robots Collaboratively in Our Homes: "Mum/Dad, When Can I Play With It?"

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Abstract
Teaching postgraduate systems engineers, project managers or cybersecurity managers to test and evaluate modern complex systems requires them to evaluate a system with a degree of autonomy, some internal programming variables and some external mission and environment variables. Prior to COVID-19, students did this in collaborative groups in intensive attendance classes with a small line-following robot as the touchstone for their exploratory-based learning. Facilitated closely by the lecturer, teams would apply test design methods to determine and rank significant factors. They would then test again to model the robot and validate their modelled predictions for their robots across learning groups in a '*whole class*' capstone exercise. The COVID-19 restrictions across Australia forced the teacher and students to do the same collaborative learning in homes. Families often got involved in developing racetracks, procedures and testing for their '*adopted*' robot. At the same time, test runs would be '*farmed out*' between different homes, and results would be discussed extensively online. Contrary to the lecturer's expectation, the careful shift to distance learning brought considerable social learning benefits and valuable workplace lessons for students in organisation and communication. Pedagogical and curricula guidance is provided on structuring any such exploratory online pedagogy for these social learning benefits and avoiding some of the pitfalls.

Keywords: Exploratory-Based Learning, Online Learning, Collaborative Learning, Vygotskian Pedagogy

Introduction

Many universities and schools have documented the impact of COVID-19 in forcing additional online learning. The impact on students and teachers has been demanding, exposing many disadvantages and advantages of the technologies used and some inconveniences and conveniences for students, families and teachers (Akpinar, 2021; Al-Areibi, Dickson, & Kotsopoulos, 2022; Cellini et al., 2021; Charbonneau-Gowdy, Pizarro, & Salinas, 2021; Logan, Ogurlu, Garbe, & Cook, 2021; Yeboah, 2022). According to Charbonneau-Gowdy et al. (2021), '*Recent stories from practitioners abound with reports of absenteeism, cameras and microphones turned off, inaction in forums and a general reticence on the part of learners to engage online.*' They argue that the poor engagement '*lies in the conventional instructional designs being used in these spaces and the teaching, learning and assessment practices they support.*' Logan et al. (2021) emphasise the importance of positively involving the student's family in home-learning education during asynchronous learning, while Al-Areibi et al. (2022) emphasise the need to develop a sense of class community during online synchronous learning sessions to help motivate students. Such research reinforces that contemporary e-learning theory can improve teacher practice. Equally, teachers may improve pedagogy from their experimentation and offer it to peers (Kepka, 2022). Such evolution is likely more straightforward in higher education, where the transition to e-learning was already underway before COVID (Allen, Seaman, Poulin, & Straut, 2016; Lay-Hwa Bowden, 2022; Swist & Kuswara, 2016).

This research article documents one teacher's serendipitous experience during COVID restrictions with modifying a postgraduate subject from face-to-face intensive teaching to online. The subject is *Advanced Test and Evaluation Techniques*. It is part of postgraduate master courses, mainly in systems engineering and project management. The teacher had previously been asked to consider moving this subject to an online mode like his other subject, in part to improve its reach and profitability. The teacher was reluctant, convinced that the inquiry and problem-based learning on a complex system needed close student interaction and teacher mentoring that would not transfer online. COVID restrictions provided the impetus for the move online. The teacher is an experienced educational researcher and online teacher using Vygotskian approaches and student peer critiquing. So despite his scepticism, he applied much theoretical and practical experience to the task. Student engagement in 2021 was impressive and sustained in a second online instantiation in 2022. The theoretical basis for the pedagogy used is outlined so that other teachers may seek to emulate the online approach in other contexts and to inspire future educational researchers to try the mixed approach to online subjects.

Literature

Recent meta-analytical research by Lai and Bower (2020) of 73 systematic literature reviews focused on technology in education reports that '*most of the reviews found that the use of technology improved learning outcomes and affective perceptions.*' Further, '*approaches involving interaction, gamification, constructivism, student-centred learning and feedback were most effective.*' In this vein, the curriculum and pedagogy used in this research are multi-dimensional, caused by the teacher's research into calculus reform decades ago (K. F. Joiner, 1999), where multiple approaches lead to a more inclusive curriculum (K. F. Joiner, Malone, & Haimes, 2002). The basis of the approach is *Constructivist* and, within that broad field, includes *Vygotoksian* methods to create discussion and stronger conceptions. The *Constructivist* aspects are to focus initially on the foundational concepts, or '*cornerstones*,' then to scaffold increasingly complex and overlapping concepts before finally providing a unifying or '*capstone*' activity.

The Vygotskian aspects are more than establishing the now famous Zone of Proximal Development (ZPD) and extend toward evolutionary instruction akin to the interpretative research essay by Nardo (2021). There is an extension from the ZPD to guided discovery learning as set out by Glassman, Lin, and Ha (2022) in their three steps of preparation, volitional activity, and then evolving the scientific concepts into more organic, unified concepts through continued experimentation. Preparation involves '*establishing active interest for engaging in problem-solving activity*.' This stage also involves establishing '*trusted relationships*' where they cooperate '*on a problem as credible interlocutors/compatriots*' and as an '*interconnected community*.' The volitional activity is about creating opportunities for student groups to discover that '*their current conceptual thinking is not capable of finding a satisfying solution*' and then to find '*alternative approaches*' for their problem. The final stage is to exploit the proximal development in continued experimentation '*to integrate new ideas and thinking into their conceptual system*.'

This approach relies on collaborative learning and dialogical teaching (Reznitskaya, 2012; Vygotsky, 1968), extending on the author's research into the benefits of structured peer critiquing (K. F. Joiner, Rees, Levett, Sitnikova, & Townsend, 2021a, 2021b). According to Glassman et al. (2022):

> *Without interpersonal relationships it is far less likely learners will be motivated to voluntarily pursue difficult tasks and/or be willing to turn to others when they fall off the end of their ZPD in that pursuit. Successful instruction is dependent on others finding entry points for productive input into shared activities. This includes learners being open to new possibilities, and interlocutors being willing to offer appraisal and input with confidence and without judgment.*

Collaborative learning research reinforces the importance of the interactive mode for its efficacy. It is defined as '*instructional settings that allow a group of learners to collaboratively develop knowledge and understanding beyond the information contained in the given materials by building upon one another's understanding*' (Menekse & Chi, 2019) In particular this research uses group presentations online to have groups '*provide and receive feedback, ask each other questions, propose arguments and rebuttals, elaborate on each other's ideas, and so forth*' (Menekse & Chi, 2019).

Student engagement is generally accepted (Fredricks, Blumenfeld, & Paris, 2004) to have three aspects: '*i) behavioural engagement (i.e., active participation in academic-related tasks), (ii) emotional engagement (i.e., positive feelings experienced when performing academic-related tasks) and (iii) cognitive engagement (i.e., investment of mental energy and effort in thinking and learning)*' (Zhoc, Cai, Yeung, & Shan, 2022). The research by Zhoc et al. (2022) reinforced '*that wellbeing is positively associated with student engagement in online learning*' and that '*the positive association between the two remains valid even with the change to the mode of online learning*.' Further, they found that well-being is associated with cognitive reappraisal strategies, whereby students cognitively reflect on the emotional aspects. The cognitive challenges of teaching are significant and varied (Chew & Cerbin, 2021), especially online. The benefits of cognitive reappraisal to learning around retention and well-being are well documented in children (Davis & Levine, 2013), and the work by Zhoc et al. (2022) begins to extend that to online tertiary study. Similarly, research by Lay-

Hwa Bowden (2022) noted that for blended learning (i.e., primarily online), '*behavioural engagement was found to strongly determine students' well-being, self-efficacy and self-esteem*' and '*affective engagement determined institutional reputation and transformative learning*'.

The benefits of a pedagogy based on open-ended problem-solving through guided discovery continue to be documented, for example, by Mira Pratiwi, Gusti Putu Sudiarta, and Suweken (2020). Such an approach can also be called '*authentic project-based learning*' (APBL), defined as '*a pedagogical approach that prepares students to solve real-world highly ill-structured problems*' by having, inter alia, '*student teams take on one project spanning the length of the class*' (Rees Lewis, Gerber, Carlson, & Easterday, 2019). Gallagher (2015) outlines problem-based learning (PBL) using the following seven criteria from Barrows and Tamblyn (1980):

> 1. *Learning is initiated and framed in the context of an ill-structured problem.*
> 2. *Ill-structured problems are interdisciplinary.*
> 3. *Learning is collaborative.*
> 4. *Information learned during independent research is related back to the problem.*
> 5. *Student's self- and peer-assessments are integral to class activity.*
> 6. *Teachers' assessments of students are consistent with the goals of PBL, and*
> 7. *Students become increasingly self-directed over the course of PBL experiences.*

Much of the pedagogy for criteria four through six can be in students presenting their solutions to the class community with open question and answer (Jin, Jiang, Xiong, Pan, & Zhao, 2022; Li, Moorman, & Dyjur, 2010). Such activity allows them to compare mental models and innovations, which adds to creative thinking and apprenticeship. In addition, the efficacy of inquiry-based peer-assisted learning has been established in several educational research contexts, showing increased student engagement, practical skills and process-specific knowledge (Brown, 2016; Gallagher, 2015; Jin et al., 2022), including by Li et al. (2010) in an online context.

Methodology

The subject has run yearly since 2017, in baseline face-to-face from 2017 to 2020 and twice online, 2021 and 2022. The baseline has run with between 10 and 24 students, while the 2021 and 2022 online versions had 13 and 17 students, respectively.

No deliberate research was undertaken when adjusting this curriculum, as it was done at short notice due to COVID restrictions. The extant records were combed and compared to theory to help explain the unexpected success. Student feedback comes from a standard set of university post-course records known as '*myExperience*' to improve the overall student experience. The questions used are available at the link:
https://www.teaching.unsw.edu.au/myexperience-survey-questions

For the baseline course, students in 2017 had agreed to be videoed for public relations, and several images used for the baseline course come from that video which can also be viewed (https://www.youtube.com/watch?v=ZK8dmC10AVo). Students in the online version also used a student-based forum on the subject's Moodle page, which was analysed to see what communication was being undertaken by word frequency and with some quotes that students agreed could be used if anonymised. Students also volunteered to provide pictures from home that they agreed could be used for the conference.

No ethics approval was sought as the student comments and contributions are anonymous, have been agreed upon by the students individually and were collected for subject improvement, which includes this article.

Baseline Pedagogy

The subject outline remained unchanged between the baseline and online versions. The full subject description is available at the link: https://www.handbook.unsw.edu.au/postgraduate/courses/2019/ZEIT8034. Part of the 2022 subject outline is as follows:

> *Techniques taught include how to construct T&E plans to first screen for the key factors effecting response of a system, then model that system's performance and finally to validate performance of a system and its model.*

The robot system shown in Figure 1 is a touchstone throughout the subject whereby students return to it to apply and understand theory practically. It was chosen because it is exciting and the variables affecting its performance are internally programmed and externally through track variability. Such systems are complex to try to optimise with many different approaches.

Figure 1: Line-following robot used as the touchstone system in the subject (2017 video).

The learning objectives below for the subject also did not change between the baseline and the online versions:

1. *Develop robust (rigorous) test methods and data collection plans to account for system variance in multi-factor systems ….*
2. *Systematically assess and identify data ….*
3. *Analyse test data … using graphical and multiple-response regression analysis to screen significant factors, determine adequacy of models and determine confidence in performance.*
4. *Evaluate (relate) test results from data analysis to determine design and operational significance …*

On Day One, in intensive mode, the baseline pedagogy taught students the objectives of test design and analysis techniques, refresher statistics and a measurement system analysis technique. Students then conducted basic familiarisation on the line-following robot by building any continuous circle track using black tape on whiteboards before using a stopwatch to time the robot's laps. The measurement system analysis (MSA) technique estimates the measurement error within the variance over several different robot settings (runs), different operators and repetitions. This exercise is challenging but involves a relatively simple theory to apply. This activity ensures self-forming collaborative groups of three to five students establish a working relationship. The teacher and a tutor constantly roam and mentor students whenever they stall for lack of understanding, always providing multiple options wherever possible for techniques to encourage student ownership and diverse outcomes. A student group working on their techniques is shown in Figure Two. A wrap-up session has student groups outline and compare their results.

Figure 2: Students preparing test run materials to analyse significant factors in the baseline face-to-face mode (2017 video).

On Day Two, in intensive mode, the first theory on techniques for screening the most significant factors in any system is introduced. Students then return to their groups and use fundamental cause and effect and process flow techniques to form candidate factors to control, keep constant and tolerate as noise. These factors are grouped in a '*design of experiments*' diagram (Figure 3) before they execute a designed test to determine the most significant factors affecting the robot's completion time. Again, a wrap-up session has student groups compare results, with one of the main points of difference being whether they chose a two-level (linear) or three-level (quadratic) screening test design. The proportional-integral-derivative (PID) controller and basic acceleration principles ensure that those who chose a three-level design are rewarded for their extra test runs with more detail. Track production across multiple runs ensures that efficiency is always considered and discussed. Varying robot settings also cause some reliability concerns when the robot cannot stay on track so that some groups will strategise and explore those 'edge conditions' with an additional output of failure or success. Finally, the binary output creates some segway to later theory on logistics regression to get a better probabilistic prediction.

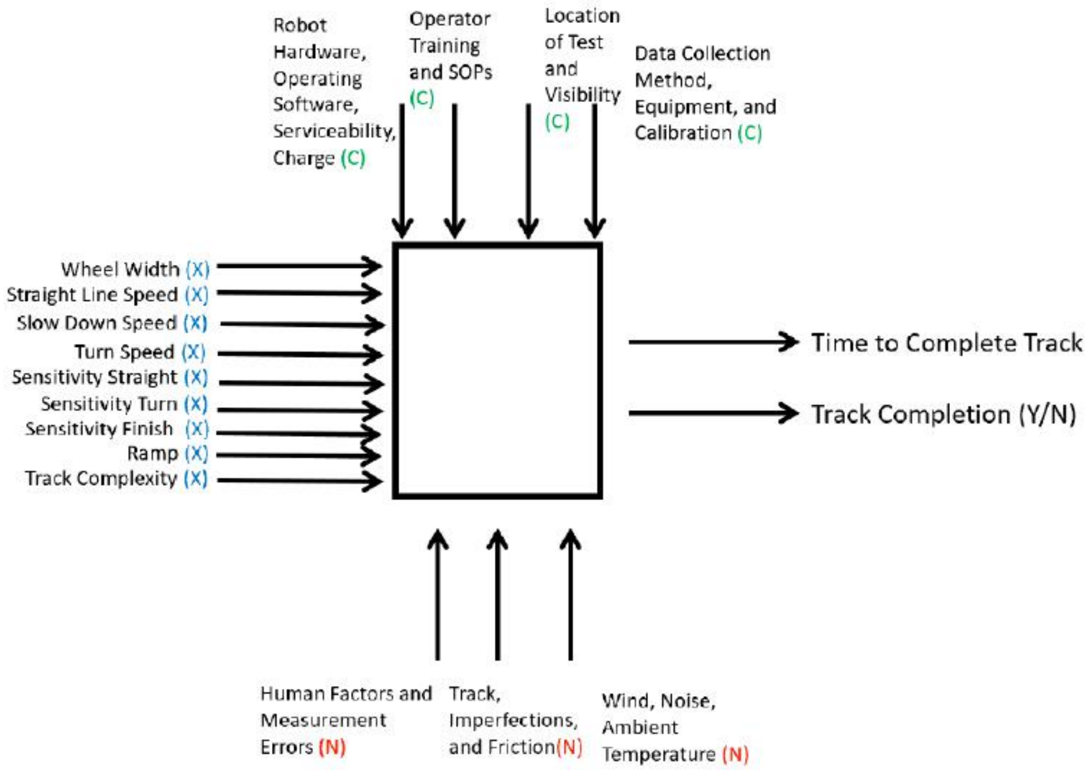


Figure 3: Example of multifactor and multi-output diagram used by students.

After more theory on modelling test designs, Day Three in intensive mode builds a more involved multi-factor model of the robot's performance for each group. Student groups usually have different track and robot setting factors and even different outputs; some will use velocity achieved and others distance. There is usually strong student ownership of their model and approach at the wrap-up session on Day Three, which is important to a shift in focus for Day Four. The switch moves from characterising the robot's performance in a model to validating the robot's and the model's usability. Validation test design theory is introduced and then used with the whole-course participation to generate a set of validation tracks. These validation tracks usually vary in length, corner diameter, number of corners and number of straights. Student groups then predict the performance of their robots on each validation track, both average completion time (or velocity) and expected variation on each track, choosing individual group robot settings if they wish. Student groups are then assigned different validation tracks that they then have other student groups visit to host the testing (Figure 4), which is essential for independence and to create constructive discussion. Student groups are usually surprised by their poor performance on some tracks due to a lack of variability and the final factors in their robot characterisation. A wrap-up session confirms how groups went relative to their predictions and creates lots of discussion.

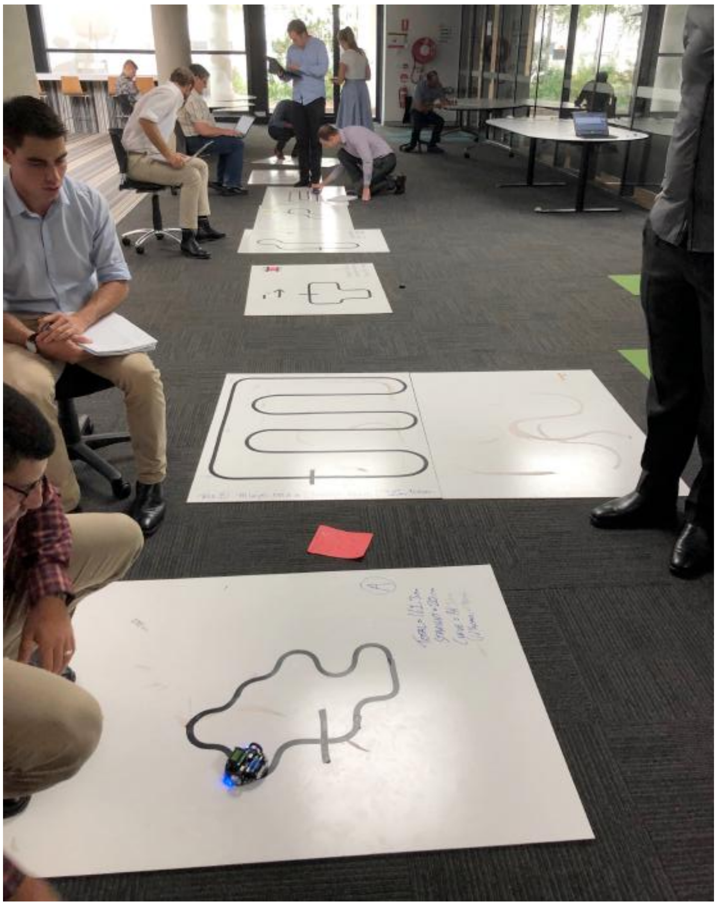


Figure 4: Students undertaking whole-course validation testing in face-to-face mode.

The intensive subject usually has some other theory and a knowledge test on Day Five. Students use the following months at home in part-time mode to repeat the process on a system of their own choice as an individual follow-up assignment.

Distance Pedagogy

The primary concern in moving the subject online was preserving student interaction. Each student was required to buy a robot and tracks, costing about AUD 250, organised well in advance. Student groups were still self-forming to encourage early communication and ensure students would respond constructively. A student forum on the subject Moodle page provided the means for communication. Students often sought to create groups in common cities to get together for testing, such as Melbourne, Canberra or Sydney. However, some recognised that they would be isolated and formed entirely online groups, for example, '*Work From Home (WFH).*' One of the more creative examples of group seeking is given below, albeit heavily redacted to ensure anonymity:

> *Hello everyone,*
>
> *I am still without a group so I am keen … A little about me:*
> *1) 4+ years in supporting …*
> *2) 1-2 years experience in …*
> *3) Recent experience in ...*
> *4) knowledge of …*
> *Not much experience but a hard worker.*

Lectures would occur for two hours in the evening one night a week, and tutorials and group presentations also last for two hours on a second night later in the week. Students sought the late time (7-9 pm) to allow sufficient time after work and family commitments. The gap between lectures and tutorials was to allow time for refreshing theory. Attendance for lectures was usually around 80 per cent, for tutorials around 50 per cent, and the assessed student group presentations around 95 per cent. One of the most significant concessions was only to have students perform the test design and analysis process on the robot system and not the second system of their own later. Instead, the former Assignment Two (Table 1) is replaced by an Application Proposal that they complete capturing how they would use the new techniques in their work or hobby. Students are assessed for group work through group presentations and then reflect individually on the outcome in submitted answers. In general, group presentations prepared students well for such reflection, especially the insight into other groups' approaches. The teacher would mentor groups a little during their presentations for everyone's benefit and in feedback to each set of reflective questions. There were three student groups in 2021 and five in 2022.

Student Interaction

Student interaction was high, beginning with establishing groups, overcoming logistics, and familiarising themselves with the robots and their track production. The teacher deliberately set high expectations for students to be able to program their robots and produce tracks so that students communicated and solved in groups and across the whole course using the forum. Four weeks were allowed for the set-up and the first somewhat benign exercise of an MSA, nearly a third of the time available, to get groups working effectively. Two examples of groups sending photographs are in Figures 5 and 6, while a Word Cloud of the student forum from 2021 at Figure 7. Figure 5, when expanded, actually shows the program used and what to vary, while Figure 6 attests to the results by '*snap chat*' for authenticity!

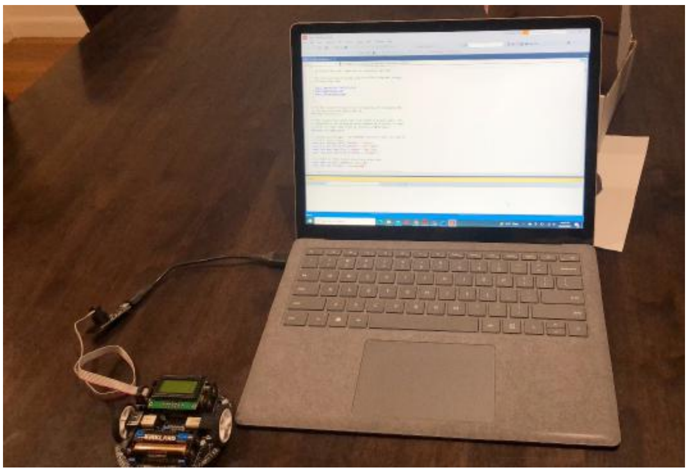


Figure 5: Home set-up program (student supplied).

Figure 6: Exchanging data between students - Run No. 2, Time on Track (student supplied).

Figure 7: Word cloud from Student Forum in 2021 analysed using MAXQDA®.

The Word Cloud analysis shows that group location is important and that key knowledge terms like the average and variance estimates (Y-hat, S-hat) and challenges like PID are being discussed. Pleasingly students are showing politeness like '*Hi*', '*happy*' and '*Cheers*' in their correspondence. What the Word Cloud does not show is the use of emojis, like the correspondence below from 2021:

> *Hi guys, We are planning on sending out the results tonight (tomorrow worst case). Just waiting on one more member* 😟.

These emojis are seen to ease potential tensions among and between student groups.

Student Feedback

Student feedback was surprisingly positive, especially concerning the learning community and subject relevance, as shown in Figures 8 and 9. The student comments portrayed on these graphs are from the open comment questions given earlier. They are selected to appear in the theme most applicable, such as learning community or relevance. The presentation of results to these questions (given earlier in methodology) unfortunately changes between 2021 and 2022. The 2021 figure shows the percentage of students agreeing with the question in this subject to any extent relative to the school and faculty, being 100 per cent and thus higher than the normal. The 2022 figure shows the breakdown of students strongly agreeing, agreeing, disagreeing, and strongly disagreeing. In 2022 one student became disaffected early and terminated the subject after the survey. Notwithstanding, the 2022 results are robust for relevance and learning community.

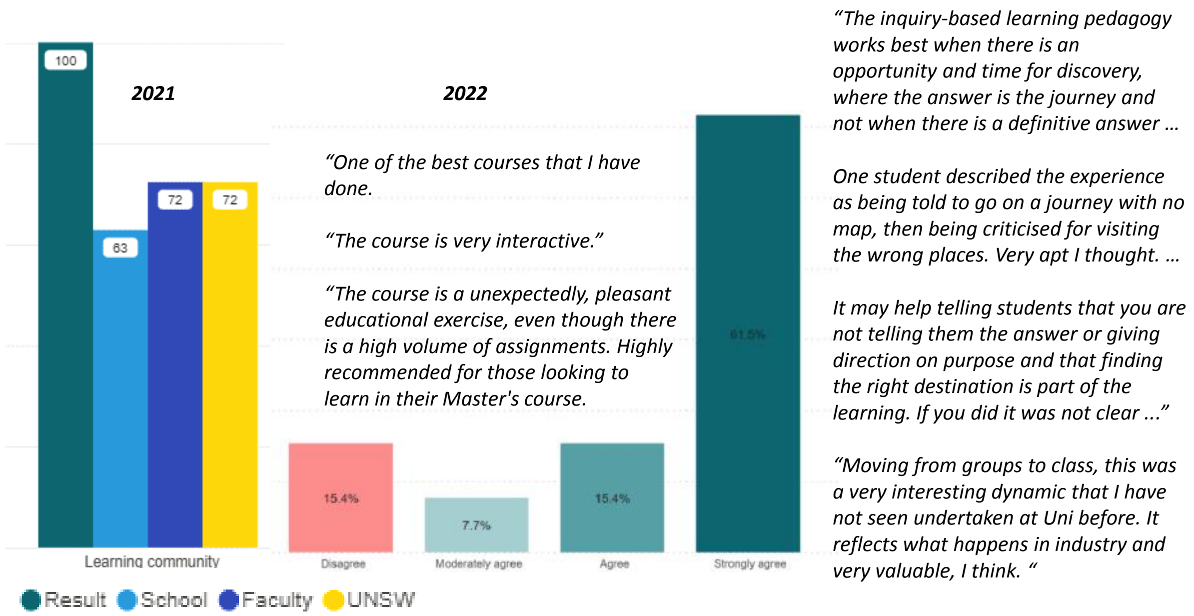


Figure 8: Student *myExperience* data related to Learning Community.

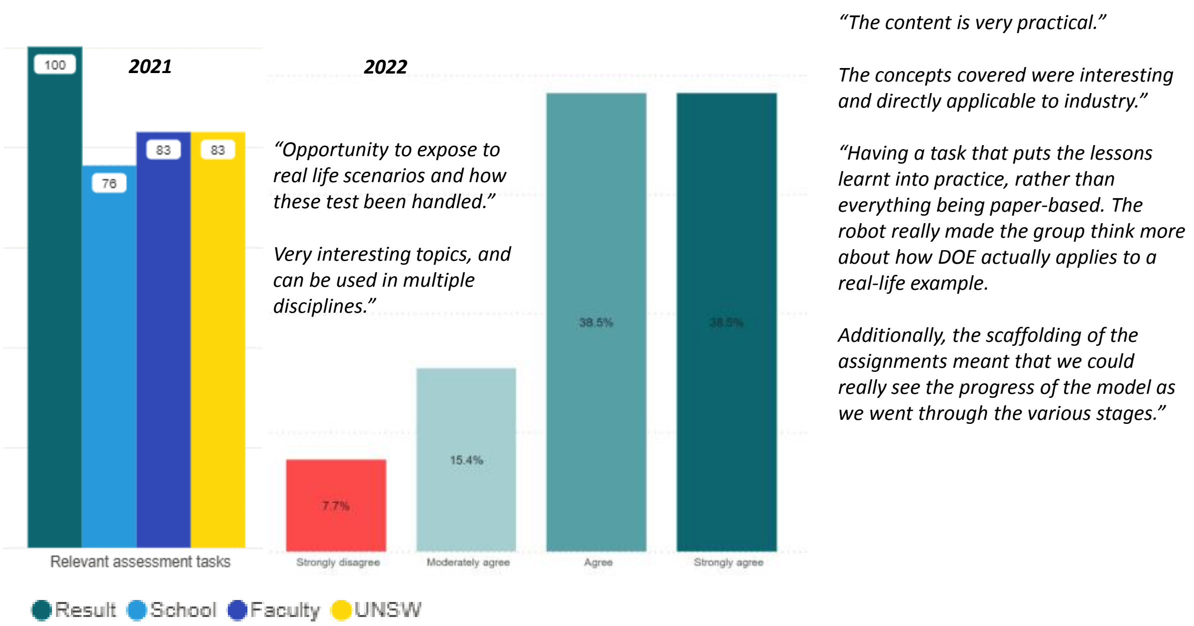
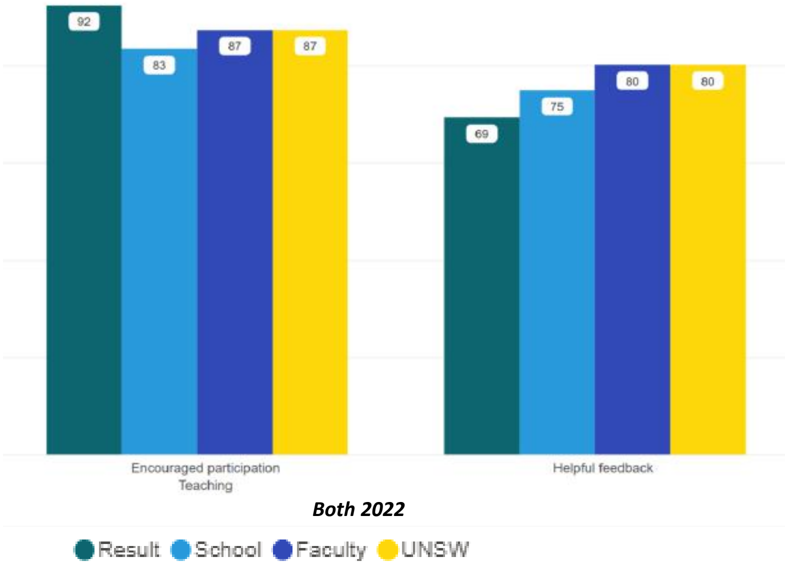


Figure 9: Student *myExperience* data related to Subject Relevance.

Student comments on encouragement and mentoring feedback were less favourable, comparable to the school norms or below in 2021 (Figure 10). The teacher devoted more time to mentoring feedback in 2022 but still had fair criticism. Students invested more time in the subject due to the engagement and inquiry-based approach and so appeared to expect comparable effort in feedback. Also, students found the lack of a 'perfect answer' frustrating, especially for solutions with mathematical aspects where they usually appear to expect a greater degree of absolutism. This change is partly due to one of the subject's objectives to account for the variance and noise in a real system. Finally, students quickly discerned that the teacher was allowing a diversity of approaches between groups to evolve without direct correction, again to help learn important lessons, which they later appreciated but did request a more honest declaration concerning inquiry-based learning upfront. A tutor has been sourced for 2023 to assist, in part, in the hope of capitalising on improving student numbers expected from greater availability online.



"Thus far in the 8 units I have been engaged in, the few live sessions I have been provided by lecturers have primarily been word for word reading off powerpoints .... Dr Joiner engaged the course regularly and provided in-depth lectures and tutorials which greatly assisted in understanding the course content and bettering my abilities ....

It is a little frustrating at times, when it is not explicit that the students are expected to learn by inquiry - it could be made a little more explicit.

There is an extremely large amount of group work for a remote (online) course.

Significantly more time was required for this course than for other courses I have taken."

Figure 10: Other Student *myExperience* data not grouped.

Teacher Observations

Several direct observations are made by the teacher regarding the move online of this subject where these aspects have not already been made through student feedback. Some observations about what theories may have influenced the shift online will be made in the discussion section later, as these are propositional.

The first significant observation is that students' families play a part in the online acceptance, engagement and practice of this subject because it occurs in the family home. For some students, it is simply a partner or work colleague, but for many, it involves children of various ages. The baseline course already had an individual exploratory assignment done primarily at home or work, where the family often played a part in the choice of the capstone system. However, the fully online subject meant that the use of the robot to elicit play now occurs in the family home, along with the seminal understanding of cornerstone concepts being played out to the family members and peer students in groups. Explaining a new concept to student peers for the first time can be difficult, but explaining it to cherished novices early on can have a reinforcing effect on students. This value comes in student group presentations, especially those who cannot congregate for testing, as the coopted assistants are varied and valued. An example of a student's son helping test in the family home is in Figure 11.

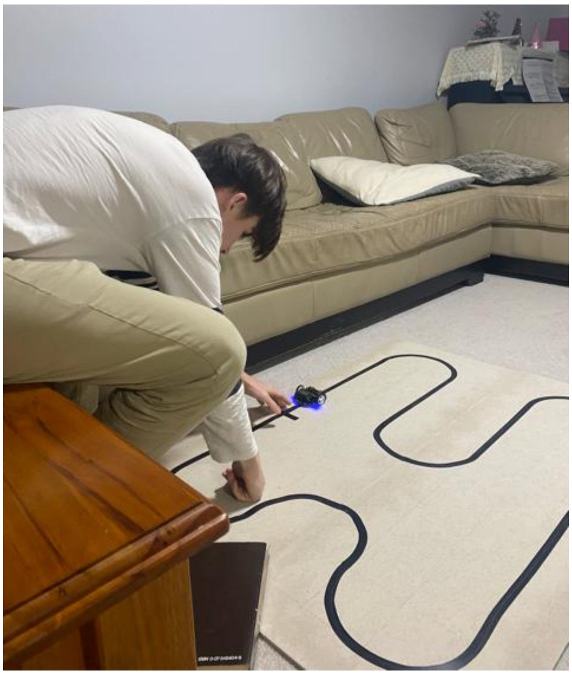


Figure 11: Testing at home with family assisting (student supplied).

The second observation is that mentoring can be harder online, requiring active checking often. This checking seemed natural in the face-to-face class as you would look around the room at groups and see progress or hear difficulties through raised voices or group members doing disparate things. The teacher had to make a habit of reaching out just before weekends or at the tutorial held late each week to make sure the weekend test activities were appropriate and not going to set students back. A second check on a Saturday evening was necessary to pick up queries midway through likely test periods. This check sounds daunting for busy teachers, but given the assessment plan (Table 2), it is three to five critical weekends in a 12-week semester. Given the earlier pedagogy about allowing different paths, this balance between hands-on and hands-off can be hard to find. An example of poor student-teacher correspondence is the one below from 2021, where students wasted an entire weekend on a poor MSA design and were advising the teacher of the second weekend of testing.

> *Keith,*
> *We haven't done the screening yet. The initial runs that were part of the MSA didn't … The Screening design that XXX provided has not been completed, and after our review, we have redesigned the screening design in what we think is a more appropriate design. … The intent is to complete the screening testing this weekend … Happy to discuss further over the phone also. Thanks in advance.*

A better example of student-teacher correspondence is the one below, checking a test design before implementing it.

> *Hi Keith,*
> *Our group have finally settled on an L-18 7-factor screening design. If you could have a quick glance over it and confirm we are on the right path before we get too far down the rabbit hole, that would be great. We still aren't sure how … but hopefully, we will figure that out as we complete more of the course! Thanks* 🙂

A third observation is the conduct of the student group presentations. In 2021 students did both student group presentations and put that into a portfolio report; however, it was overkill. The PowerPoint group presentations were more than enough in 2022 to assess the group components, and there is already individual reflective reporting to satisfy that skill. Also, in 2022 the teacher deliberately encouraged other student groups to question rather than being the only questioner. This pedagogy often required a Socratic exchange to initiate questions, usually by prompting a group that presented earlier as to whether the subsequent group's differences had been sufficiently explained. Once students had performed one individual reflection on their group's results, they often welcomed the chance to question other groups. The individual reflections must be due about three days after the student group presentations to realise this value, so the differences are fresh in the students' minds.

Discussion

The curriculum and pedagogy for the Advanced Test and Evaluation Techniques draw from many educational theories outlined in the literature earlier, summarised in Table 1.

Theory	Explanation	Reference
Guided discovery learning	1. Establish the touchstone system (robot) as a credibly representative complex system to test. 2. Establish trusted cooperative relationships early through self-forming teams, shared robot familiarisation & an achievable exercise that they brief. Activity finds initial thinking only partially solves & leads to alternative solutions (volitional). 3. Iterate the proximal development of team-based robot exploration to build concepts of screening, modelling & the capstone whole-course validation.	(Glassman et al., 2022)
Collaborative learning	Group work & online presentations are assessed, but the focus is progress check (formative) with whole-course Q&A.	(Menekse & Chi, 2019)
Dialogic teaching	Teach as a co-inquirer & avoid a perfect solution. Allow inelegant solutions (i.e., tracks & 2-level test designs) for efficient testing	(Reznitskaya, 2012; Vygotsky, 1968)
Informal Peer-critiquing	Student groups naturally check work they must co-present but also foster critiquing between groups through whole-course Q&A	(K. F. Joiner et al., 2021a, 2021b)
Student engagement	Behavioural engagement. The robot is fun & yet complex, so it elicits play & desire to control (program) & challenge (tracks). Emotional engagement. The robot is present in the home, explained to friends & family. Commitment to a group as all present. Cognitive engagement/Reappraisal. Task requires estimations & hypotheses where test results, when presented to the whole course by all groups, require reappraisal & reinforcement.	(Fredricks et al., 2004) (Zhoc et al., 2022) (Davis & Levine, 2013)

Problem-based learning	Characterising robot performance is ill-structured, with uncertainty in purpose & many pathways across a semester. Teams undertake independent research & relate to the problem with the group & their individual reflections throughout—increasing self-direction.	(Barrows & Tamblyn, 1980; Gallagher, 2015)
Authentic	Credibly representative complex system to test & one project spanning class length.	(Rees Lewis et al., 2019)

Table 1: Alignment of Pedagogy with Theory and Research.

It may seem to many teachers that there are too many different pedagogies in one subject, and some focus may be better. Indeed, students occasionally find the multitude of approaches disconcerting, and some argue for less pedagogical diversity. Inevitably students have their favourite ways of learning, which they usually want teachers to concentrate on. However, Sanger (2020) noted that "*evidence suggests most students do not have a single 'learning style' and in fact learn best when exposed to a range of modalities and representations*." Diversity of pedagogy is therefore inclusive of different learning styles in the Universal Design for Learning (UDL) tradition (Behling & Tobin, 2018; Sanger, 2020). Furthermore, for university programs, these diverse learning skills are often expectations of professional practice (i.e., presentation, report, Q&A).

The key is for students to communicate. Hence to contribute to other teachers and researchers emulating the success of this subject and its move online; the following suggested communication strategy is recommended:

- Forming groups on the forum got them communicating.
- Progressive challenges kept them communicating.
- Family communication reinforced learning value.
- Student presentation back to whole-course as groups got them consultative and constructively competitive.
- The final challenge exercise got group-to-group communication.

Another more evolved way to express the pedagogical strategy is through what can be referred to as Vygotskian learning interactions that propagate or grow, as summarised in Figure 12.

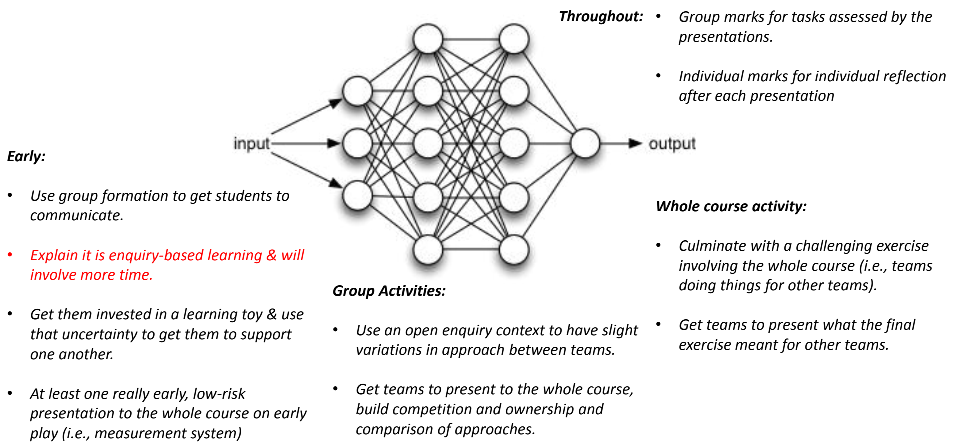


Figure 12: Generic principles proposed for propagating Vygotskian learning interactions.[1]

[1] The guidance in red was not implemented but was included for the future based on student feedback.

Conclusion

Due to COVID restrictions, a postgraduate subject with significant problem-based and guided discovery learning was successfully transitioned from face-to-face to online. Student feedback and teacher observations found that the online mode maintained a positive learning community, subject relevance, and good other ratings. A communication strategy was developed and is provided for other teachers to help maintain student collaboration and informal critiquing when teaching with an ill-structured problem online. A key to the strategy is successive group presentations made achievable by starting with a relatively simple early task with time to absorb the context and team dynamics. A whole-course capstone activity with critical cognitive reappraisal and interaction between student groups also successfully transitioned. A disadvantage of the online problem-solving approach is that it is time-consuming for students in ways that appear more noticeable to students than face-to-face. Teachers must also check strategies for problem-solving with student groups before implementing these, as there are not the incidental cues of face-to-face learning.

A curriculum and pedagogical approach to emulate online success is presented based on propagating Vygotskian interactions. This approach warrants structured research, as this single subject is small, personal to one teacher, and limited to a single subject context and educational level.

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