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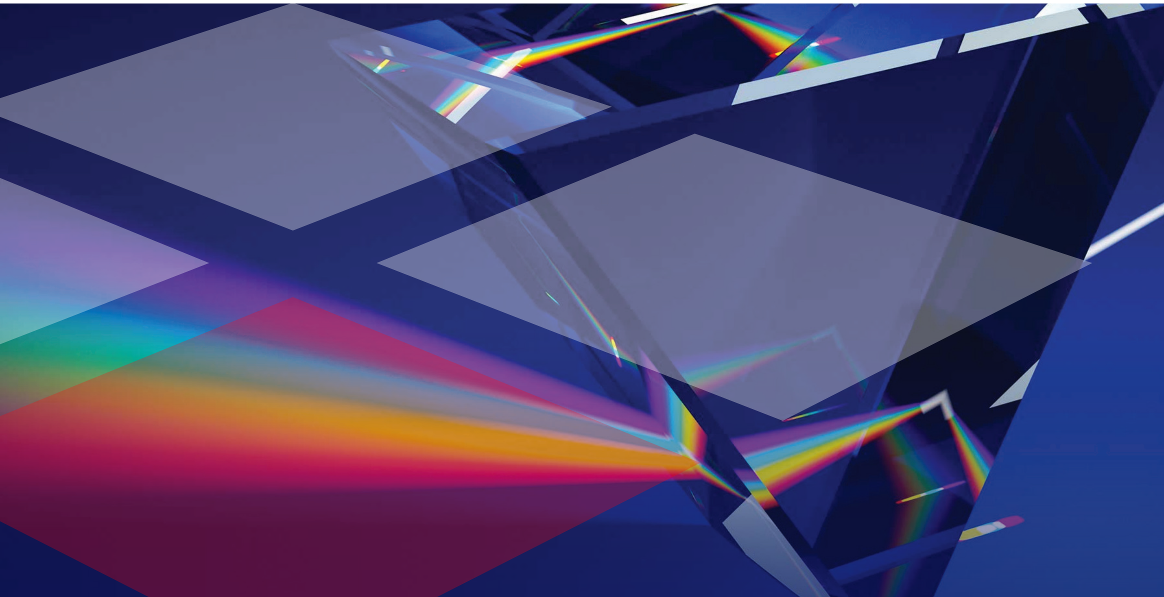

Collaborative teaching to prepare Year 11 Physics students for university – Lessons from the second iteration.

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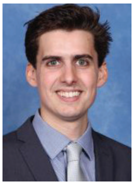

Dr Matthew Hill is the Director of Research in Learning & The Barker Institute with a focus on professional learning, research and innovation in the School. He teaches Physics and the new Science Extension course at the School which introduces students to scientific academic research. Matthew's doctorate reflects his passion for science education focusing on Representational Fluency amongst physics students at school and university. He has published in leadership, education and science journals and been involved in course development and teaching at The University of Sydney and The University of Western Sydney. He has also completed a Graduate Diploma in Divinity at Ridley College in Melbourne.

Dean Johnston is a Science teacher, specialising in Physics. In 2019 he was appointed to the role of Assistant Co-ordinator of Science (Stage 4). He holds a Bachelor of Science (Physics) and a Diploma of Education from Macquarie University. He was excited to join the Barker teaching staff in 2017, particularly as he is a former student whose character and intellect was substantially developed by the teaching and guidance he received whilst at Barker. He is passionate about instilling a deeper appreciation of science in young students and is continually seeking ways to challenge the status quo of science education in secondary schools.

Nonie Taylor is a Physics, Earth and Environmental Science, Mathematics, and iSTEAM teacher. Prior to teaching, she worked for fourteen years as an advanced wastewater engineer for a water utility company. During this time she was concerned by both the absence of female representation in the water industry as well as the shortage of creative, passionate young people pursuing engineering as a career choice. This drove her career change to education, where she now loves being involved in helping students find enjoyment in understanding the world around them and contributing to finding solutions.

Daniel Woolley is currently Assistance Co-ordinator for iSTEAM at Barker College. He teaches science, specialising in Physics and the stage 5 iSTEAM elective. He holds a Bachelor of Engineering (Hons) and a Bachelor of Science (Physics) from Australian National University and a Graduate Diploma of Education from Australian Catholic University. He taught Mathematics prior to joining Barker College in 2017 and is passionate about students developing skills they can use across disciplines and throughout life.

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Abstract

For the second year, many of Barker College's Year 11 Physics classes have taken on a new format modelling university teaching to promote executive function, resilience, independence and self-reliant learning amongst the students. At high school, many students can perceive that their learning is their teacher's responsibility leading to high university attrition rates when students fail to adapt to optional classes, self-directed study and homework practices. Three Year 11 Physics classes in 2018 and four in 2019 were structured in a similar format to a first-year university Physics course with weekly lectures, tutorials and experimental work (along with additional support hours at a weekly Physics' "Access" session on one evening). In an anonymous survey of 56 students, 74% of respondents indicated that they preferred this week-by-week method of teaching over a lesson-by-lesson approach, more typical at high school. Particular benefits to the students included development of executive function and planning, improving ability to understand concepts and reducing stress and anxiety with a structures approach to classes and homework. In addition, the students profited from staff time being freed up for more personal counselling, support and tutoring as they progressed through the course.

Key Terms

Lecture

A lesson that is delivered to a group of students larger than the typical class size (< 25 students). This is not meant to imply mere transmission of knowledge or inactive attendees (e.g. Sharma et al. 2010). There is no limit to the method of teaching and engagement, merely the ability to deliver the lecture to larger numbers of students. When delivered to only one class of students it can sometimes be referred to as a "theory" class.

Tutorial

A lesson devoted to guiding students through problem solving. May involve practical, conceptual, or numerical problems or activities.

Tutorial problems

A set of problems written for the students to allow them to grow in their understanding of physics and develop their problem-solving skills. At least some of these problems should be done during a tutorial lesson but all are to be completed before the start of the following week.

Experiment

A scientific test including an aim, method, results, analysis, and conclusion.

Team-teaching

A coordinated approach among multiple teachers taking responsibility for a group of students. It usually involves different teachers facilitating different parts of the course.

Body

Introduction

In 2018, two of the authors trialed a new initiative with three Year 11 Physics classes involving a university-style structured week. The new NSW Physics syllabus outcomes were divided into weekly topic areas. In addition, the practical component of the course was aligned to these topic areas. Reflections on the first year were published including recommendations for future implementation (Johnston & Hill 2018).

Key recommendations included:

- Involving more teachers to bring in additional collaboration and synchronized delivery.
- Providing students with a schedule and tutorial book at the start of each module to better allow them to plan their term. Each tutorial should have a range of problems with increasing difficulty.
- Weekly short quizzes on the online learning management system, Canvas
- A common style and format for all digital and printed material
- Filming lectures and making them available through Canvas
- Increasing interactivity of lectures including interactive lecture demonstrations

Many of these were able to be achieved and there is still more work to be done to continue to increase the efficacy of this teaching method.

Course Structure: A university-style format with school-level personal relationships

Each week one topic area of content was presented Year 11 Physics students. The weekly structure consisted of an interactive lecture (or theory class), a problem-solving tutorial, and an experiment or practical tasks. Four teachers (the four Authors of this paper) and their classes were involved in 2019 (achieving the first recommendation from the 2018 teaching team). Two classes were run concurrently allowing for a common lecture in the lecture theatre and two classes were run on other lines.

Lesson 1	Lesson 2	Lesson 3
Interactive lecture	**Tutorial**	**Experiment**
Students attended an interactive lecture (or theory class) designed to cover all content required for the week.	A set of practical, conceptual, and numerical problems were completed by the students and various techniques were used to provide in-class support	Students completed a scientific investigation with aim, method, results, analysis, and conclusion to apply their understanding and continue to develop their scientific inquiry skills.

Table 1: The university-style format for Physics teaching (Adapted from Johnston & Hill, 2019)

The 2019 timetable involved one additional hour of instruction per fortnight. The additional class was used as a discretionary class for the teacher or student to decide how to best use this additional time.

Rationale: *most effective learning, preparation for university, maximum utilisation of teacher resources.*

The rationale for continuing the structure in 2019 builds on the rationale described by Johnston and Hill (2018) who pioneered the program in 2018.

At its heart is an understanding of *effective learning*. This occurs within the particular teaching structure in two ways. First, there are multiple points each week where students cover the same content from different perspectives allowing for internalisation of concepts and skills to take place. When the same content is covered in the lecture, in a tutorial, and as part of an experiment, students get to wrestle with the difficult ideas in Physics and more effectively construct new knowledge overcoming limitations in working memory (Paas, Renkl, & Sweller 2003; Sweller 1988). Second, it establishes students as agents responsible for their own learning able to use many resources, including their teachers, to progress their learning. Carpenter & Pease (2013) describe three categories of non-curricular learning strategies including Self-Regulation, Collaboration, and Academic Mindsets which are all skills developed through the new Physics structure. Providing a class schedule and giving the students access to all resources at the start of term with specified deadlines gives engages students in self-regulation developing an academic mindset where they begin to ascribe more responsibility to themselves as the learners rather than placing expectation on teachers (Fisher & Frey 2008; Mameli et al. 2019; Zimmerman and Kitsantas 2005). One particular way this is achieved is though students learning that success can correlate with meeting clear performance requirements such as weekly tutorial deadlines (McCombs 2012; Perencevich & Kett 2005).

University preparation was a deliberate part of the rationale for the course. The model parallels university instruction, especially in the sciences. Motivation and the lack of immediate teacher accountability has been identified as a factor hindering performance and retention of first-year students at Australian universities (Baik et al. 2015) and therefore exposure to the university learning-style with the additional school-level accountability is preparing these students for future learning. Lecture participation (note taking, active listening, lecture preparation, accessing resources) and effective tutorial use (pre-work, collaboration, asking salient questions, ensuring completion) were skills that taught, both explicitly and implicitly, through the year.

The four teachers firmly believe in fully utilising their *collective teaching resources* to best serve the students entrusted to them. Collaboration in resource preparation allowed for professional development in effective teaching of difficult concepts and freed up time to invest in higher-quality shared resources and individualised tutoring and mentoring of students that teachers can struggle to find time for in their busy schedules.

Changes for 2019

There were three main changes for the 2019 year.

1. Four teachers were involved rather than two. This allowed for greater collaboration and sharing of the load of resource creation. Greater professional discussions were able to be had concerning the pace of the course and particular student difficulties as four teachers were working to the same schedule with the same resources.
2. Full tutorial books were printed and distributed to students at the start of each module. This allowed students to clearly see what was expected of them in each module, allowed for them to collaborate across classes as they knew that other classes had the same tasks as them, and was crucial in allowing students to plan ahead for when they might be missing classes or catching up when absent. For example, one student spent two weeks on an international tour missing two out of the four weeks on Module 4: Electricity and Magnetism. Because of the tutorial book, with proper planning and independent work, they returned to school entirely on schedule having completed the two tutorials that they were away for and only needing to catch up on the practical tasks.
3. Each module concluded with a diagnostic test written by the staff member responsible for that unit. In line with the principles of formative assessment, this diagnostic test was marked by fellow students as a learning exercise and students were to re-attempt and resubmit their work until they achieved a mark of 80%.

2018 Recommendation	2019 Implementation	2020 recommendations
Involving more teachers to bring in additional collaboration and synchronized delivery.	The staff involved grew from two to four teachers. Collaboration was greater as each teacher took responsibility for a Year 11 module and were able to discuss progress and planning. Unfortunately timetabling allowed for only two of the four classes could have synchronized lectures.	Request timetabling to schedule more concurrent classes, at least once per week for the lecture.
Providing students with a schedule and tutorial book at the start of each module to better allow them to plan their term. Each tutorial should have a range of problems with increasing difficulty.	With four teachers, each teacher adapted the separate worksheets that formed the 2018 tutorials to produce a common tutorial book that was used across the four classes. There were problems of a range of difficulty, but this was not always sequential or clearly articulated.	Polished tutorial books have been completed and edited. Problems should be separated into varying levels of difficulty including optional extension problems.
Weekly short quizzes on the online learning management system, Canvas	Another colleague produced weekly quizzes that were only applied to these classes in a limited manner.	Continue to ensure that weekly quizzes are aligned to content.
A common style and format for all digital and printed material	Achieved through the creation and distribution of the tutorial book and all practical tasks were completed and assessed in a similar (check pointed) format.	n/a
Filming lectures and making them available through Canvas	Technical difficulties meant that only a few lectures were recorded.	Continue to consult with the IT team to develop manageable solutions to recording lectures.
Increasing interactivity of lectures including interactive lecture demonstrations	Partly achieved through deliberate effort, but difficult to measure.	Explore professional learning courses, possibly at a university level, for interactivity in lectures.

Student reflections

During Term 3 (the final term of Year 11), participating students were surveyed to gauge the level of support for the new format. Responses were collected voluntarily and anonymously using Google forms, increasing the validity of the responses. 56 out of 65 possible students completed the survey. Two main questions asked of students included one way that week-by-week format was helpful and one thing that they prefer in other subjects that use a different format. The results are summarized below.

1. One way that the week-by-week format is helpful:

Student responses were grouped according to topic and the categories included:

- Helpfulness in planning, executive function, and preparation (25 responses fit into this category)

- Improved their ability to understand concepts (21)
- Helpful for when missing classes and needing to catch up (5)
- Reduced stress in homework and assessments (4)
- Prepared students for university (3)

Clearly students appreciated the opportunity to plan their week and know what was expected of them in class and for homework. The only homework was ensuring that the full tutorial was complete with worked solutions before the following week's lecture. Students commented "As a result of [this structure], I feel more organized in Physics than any other subject" and "It's less stressful as I knew the weekly due date for tutorials and upcoming pracs". One student simply said that it is "good for time management". These skills go far beyond Physics and relate both to learning in general and various life skills. Students took responsibility for their own learning and needed to make plans or accept the inevitable consequences.

Excitingly, many students believe that the benefits extend beyond planning and organization to an improved opportunity to learn and understand the difficult concepts they encounter in Physics. They comment "the week by week structure allowed me to focus on the topic at hand more distinctly, to ensure that I understand it" and "It helps me to understand the topic completely, not having to change my mindset in between each lesson."

One of the purposes of this structure is to prepare students for university. More important than students explicitly identifying this is that they recognise the skills applicable for university that they are able to develop. University tutors exhort their students to begin tutorial work before the tutorial class so that they can answer questions but this rarely happens. Many student in Year 11 physics were attempting to do this: "I can decide when to do work in advance… the layout helps to prepare us for university" and "the tutorial allowed for at least one period per week where we could just ask out questions to help us with our work".

1. One thing you prefer in other subjects that are not week-by-week in format:

Only 37 of the 56 students were able to articulate an answer to this question. One student remarked "Nothing, the Physics structure is the best way to learn" and the categories included:

Multiple students (approximately 6) indicated that they preferred direct instruction and did not appreciate needing to find answers for themselves "[I prefer other subjects where you are] being taught the subject instead of having to teach yourself" or be expected to work for a whole tutorial "in tutorial lesson… sometimes work doesn't get done".

Other students believed that more repetition of problems and topics happened in other courses and there was more flexibility to spend different amounts of time based on topic difficulty. A few students indicated that they enjoyed the unpredictability where they didn't need to plan for class but would just be told on the day what was needed of them.

Teacher reflections

Teacher 1 - Reflections on the experience:
I found the structure useful, practical and collaborative. It has improved the organisation of my classes, making my preparation more effective. The collaborative nature has improved my teaching efficacy, confidence and provided professional development. These were developed through frequent discussions surrounding the sequencing of content into weekly sections, lecture content and diagnostic quizzes. It is also helpful to have planned and shared work expectations across classes. These expectations assist both students and teachers in planning for work and following up students who are experiencing difficulty with the content.

Reflections on student feedback:
Students in my class appreciated the structure as it broke the module down in smaller sections. They found this useful for several reasons; it allowed them to focus on a concept for a week at a time, it organised their notes and learning and they became aware of the sequential nature of their learning. Students saw the value in completing tutorial questions each week to consolidate their understanding but could develop their practices to utilise each other more as resources for learning during this time.

Teacher 2 - Reflections on the experience:
I really valued the efficiency in collaborating to produce materials and other resources. We were able to produce five full tutorial booklets by working together and were able to discuss our teaching strategies as a group. One colleague chose to produce worked solutions for every tutorial problem and the benefits of their work were multiplied as they were producing them at the exact same time that I needed them. I was able to volunteer more of my time to be mentoring and supporting my students one-on-one.

Reflections on student feedback:
Some of my students were commenting that they wanted the tutorials to be the day before the lecture, so they can ask any final questions. I am concerned that this will mean that some students don't begin the tutorial until then when it is too late. Instead, I want to keep the same structure (where the tutorial follows the lecture), but specify how may simple processing questions they should complete immediately after the lecture to have them done before the tutorial the next day.

Teacher 3 - Reflections on the experience:
I found the predictable structure of the course not only benefitted the students involved, but also benefitted me in managing my time. I knew at the start of the year when I would need to invest more time to develop lectures and tutorials for my unit of work and I was able to set aside some time during holidays to give that my concentrated effort. Knowing that it would be used by my peers gave me extra motivation to invest extra time – something a teacher does not always have time to do when working week to week preparing content. The collaboration between the teachers meant that I never felt unprepared or concerned about my ability to teach all concepts within the timeframe given, which is a great way to feel when teaching a new course.

Reflections on student feedback:
It was good to see that the students enjoyed the predictability of the course – knowing when things were due and how to best prepare for each lesson. The structure also enabled the students to better see the connection between the content covered, the tutorial problems, and how that linked to the practical investigations. This is absolutely crucial in the study of physics – to relate the theory to what is observed.

Teacher 4 - Reflections on the experience:
The true collaborative nature of this structure allows for more one-to-one engagement with students without disadvantaging other students in the class. For example, during a tutorial lesson I could be assisting a student to further develop a particular concept they were struggling with in order to answer a particular problem whilst other students would continue to work through the pre-prepared tutorial book.

Reflections on student feedback:
Some of my students struggled with less 'direct instruction' from me (despite a whole lecture of an interactive format of "direct instruction"); after that week's lecture, students were typically required to investigate the concepts independently using their textbook. Perhaps some have learned a behavior through their formal schooling whereby they expect the teacher to provide them with everything they need to know. This is less likely in senior years, and certainly not the case beyond school, so it's crucial that I support them to develop their skills in this area now.

Conclusion

It is clear that both the students and the teachers involved in this program of study believe that it is an efficient and effective way for learning and development to take place in the Physics classroom. It is hoped that lessons from this article may be able to be applied in other learning areas and year groups. There may even be a possibility for inter-school collaboration in order to best utilise the small pool of physics teaching expertise that is spread thin across the state all for the benefits of the students. Please contact any of the authors if you would like to know more.

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