



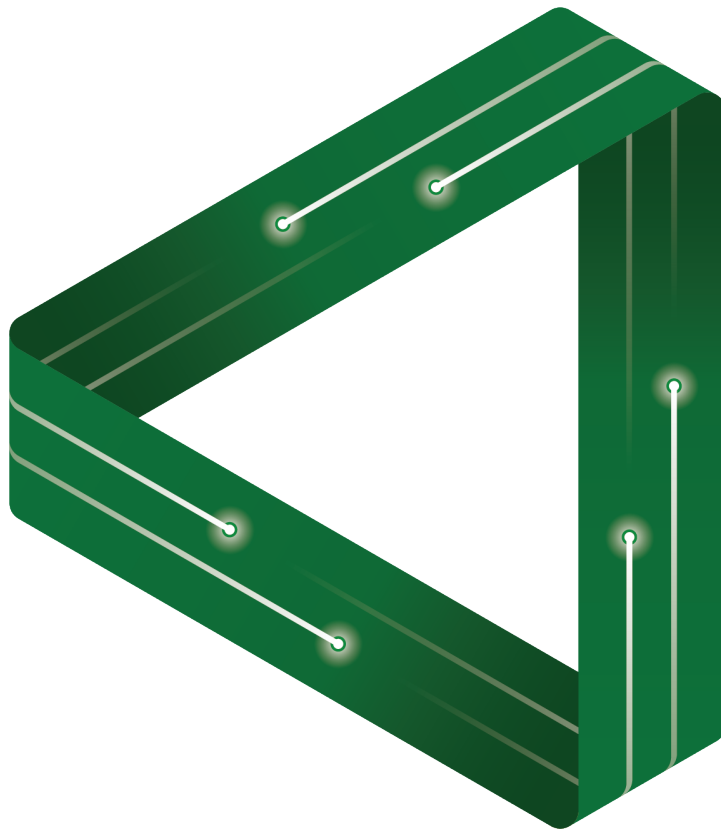
FLEET

ARC CENTRE OF EXCELLENCE IN
FUTURE LOW-ENERGY
ELECTRONICS TECHNOLOGIES

JMSS-FLEET evaluation of the Future Electronics unit, 2020-2023

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Overview

The FLEET Future Electronics Unit

The FLEET Future Electronics unit introduces the Year 10 students at John Monash Science School (JMSS) to quantum physics at an intuitive level, minimising the use of complex maths. This elective, spanning a full semester, builds on fundamental concepts to explain advanced quantum states such as superfluids and topological materials. This report is an analysis of the data from the 2020-2023 evaluation reports.

The unit covers, to varying extents, the following topics:

- Conductors, Insulators and Semi-Conductors
- Binary, Transistors and Boolean Logic
- Momentum and Kinetic Energy
- Quantum physics
- Topological materials
- Superfluids and excitons
- Particle physics
- Heat and Temperature
- Graphene and Cold Atoms
- Electromagnetics

The majority of the unit is taught by JMSS physics teachers, with FLEET members providing guest presentations and assisting in selected hands-on activities, either online or in-person. FLEET conducted presentations for the students on the following topics:

- Introduction to FLEET, its research and an outline of the unit
- Transistors and semiconductors
- Quantum physics
- Quantum computing
- Cold atoms
- Topological materials
- Superfluids and excitons
- Graphene
- FLEET lab tours.

Overall highlights

- Student engagement: Between 82 and 90% of students enjoyed the unit and found it interesting. Some of the interest was because students perceived they were learning topics unique to a secondary school.
- Future studies: There was some inconsistency between cohorts, but between 26-55% of students perceived their experience with the FLEET unit as having made them consider studying physics-based subjects in the future.
- Value of presenters: FLEET presenters are crucial. Most students (up to 97%) across all years considered it valuable to hear from or engage with FLEET presenters. Students valued FLEET scientists for helping them realise new perspectives on physics, making physics real and palpable, and facilitating their increased breadth and depth of understanding of the topics taught.



- Female representation: Evidence from semi-structured interviews suggests that female FLEET presenters enable female students to see a place for them in physics.

Evaluation

Each year, students who participated in the FLEET unit complete a survey to help FLEET and JMSS understand the learning outcomes, the impact of the unit on students' perceptions of physics (as a discipline and career) and the value and impact of the FLEET presenters. In 2021 and 2022, 11 students were also interviewed (four female, seven male) to add further qualitative data to help understand the value and impact of the FLEET unit.

Survey data and insights

The survey data was also used to identify potential problems with the unit and refine the unit content accordingly. Key findings include:

- Perception shift: many students reported a shift in their perception of physics, recognising its relevance and potential as a career path
- Appreciation for research: students valued the opportunity to learn from active researchers, which enhanced their understanding and appreciation of the subject.

Method

Strategic objectives:

FLEET's outreach activities at JMSS aimed to:

1. Enhance scientific literacy and understanding of FLEET science among JMSS students.
2. Influence students' perception of physics and the physical sciences, potentially affecting their participation in STEM subjects in senior high school and university.

Evaluation focus:

For FLEET, a greater emphasis for the unit evaluation is to increase FLEET's understanding of the following, which reflect FLEET's strategic objectives but also help us understand the impact of FLEET presenters in helping achieve these objectives:

- The unit's effect on student perceptions about the value of physics as a discipline
- The unit's effect on how students value physics as a career option (or its usefulness in a career)
- How students value FLEET presenters and how well the presenters facilitate the achievement of the above aims.
- The impact of female FLEET presenters on female students' perceptions of physics as a career option.

Data collection methods:

A survey and semi-structured interviews were used to evaluate the impact of the unit relative to FLEET objectives outlined above. A survey was completed by every student in each student cohort between 2020 and 2023.

The survey contained up to 44 questions. Most were Likert-scale questions to assess student agreement with statements that assessed the difficulty of each topic, its enjoyment, if it was presented in a way that students could understand, and whether it should be kept in the

unit. Only the questions relevant to the FLEET objectives are analysed for this report. Five of the questions were open-ended (qualitative), along with the data from the semi-structured interviews. The data from these five questions and interviews make up the bulk of the analysis in this report.

The semi-structured interviews were conducted with the students (seven male and four female) in the 1-3 weeks following completion of the unit. The students interviewed were asked the following two broad questions:

1. How has the unit made you think about physics as a discipline and as a potential career?
2. Tell me about your thoughts on the value of using FLEET scientists to help present the unit?

In 2022, two female students were interviewed about their experience, specifically with FLEET's female presenters, to better understand their impact on women in STEM. In 2021, the female students interviewed discussed their experience with FLEET's female presenters without prompting.

The qualitative data and analysis in this report are informed by constructivist grounded theory described by Charmaz (2014). Students are de-identified in this report. Each semi-structured interview went for approximately 30 minutes. Interviews were recorded and then transcribed. A constructivist inductive analysis was used with three phases of coding: Initial, focused and thematic.

The next section outlines the data from the surveys and interviews that are relevant to FLEET's strategic plan objectives.

Results

The results for each relevant question from the survey or semi-structured interviews are presented separately below. The data from the quantitative questions are presented first, followed by the data from the qualitative questions and interviews.

Quantitative

Enjoyment, interest

While not directly relevant to FLEET objectives, enjoyment and interest are considered precursors to achievements of the other criteria analysed for this report. Nearly all the students (up to 90%) enjoyed and were interested in the unit and valued the opportunity to learn about quantum physics, which is something few, if any, secondary students learn about. See students comments below and Tables 1a and 1b.

"Being able to learn more about unique aspects of physics and having scientists come in and talk to us about their research in FLEET."

"I enjoyed learning about physics that we would most likely not learn about until University"

Table 1(a). How JMSS students ranked their enjoyment of the FLEET unit topics

Level of agreement	Agree	partially agree	partially disagree	disagree
Number of students	70	69	27	6

Table 1(b). Level of agreement on how interesting JMSS participants found the topics in the FLEET unit.

Level of agreement	Agree	Partially agree	Partially disagree	Disagree
Number of students	84	65	19	5

Would this course increase the chances that you might choose to study relevant subjects in the future?

There was a varied response to this question across the survey years. Depending on the cohort, between 23% and 55% of students thought the unit increased their chances that they would study physics or relevant subjects in the future. In each survey year, however, there was also an equal or more significant proportion of students already considering studying physics.

In 2021 and 2022, only a minor proportion of students perceived the unit had no effect on what subjects they wanted to study. See Table 2 below.

Table 2. JMSS Year 10 FLEET unit evaluation 2021-23. Student question: Would this course increase the chances that you might choose to study relevant subjects (ie: Physics, Electronics, Computing) in the future?

Student response	% of student responses 2023 (2022/2021 data)
Yes - It has made me consider doing these subjects in the future	26% (55% / 36%)
I was already planning to pursue study in these fields in the future	37% (28% / 46%)
No - It has had no effect on what I wanted to do in the future	37% (16% / 17%)

If you didn't choose to pursue a career in physics, electronics or computing, do you believe that the topics that you have learned about in this course be useful anyway?

In 2020-22, 72-75% of students thought that all or most of what they learned in the unit would be useful outside a physics-based career. In 2023, this figure dropped to 55%. See Table 3. However, this question may lack some rigour as we are expecting year 10 students to understand or have worked out their future careers and general engagement with society and how such knowledge will be applicable. Responses are possibly a naive perception, but they indicate how they value the unit.

Table 3. JMSS Year 10 FLEET unit evaluation 2021-23. Student question: If you didn't choose to pursue a career in physics, electronics or computing, do you believe that the topics that you have learned about in this course be useful anyway?

Student response	% of student responses in 2023 (2022/2021 data)
Yes - all of it is useful and/or interesting	14% (14% / 17%)



Yes - most of it was useful and/or interesting	41% (58% / 56%)
Somewhat - some of the topics were useful and/or interesting but some were not	41% (25% / 20%)
No - I didn't think the majority of the topics would be useful and/or interesting	3% (3% / 7%)

Was it valuable to get to hear from and work with FLEET scientists?

This was a question added in 2023 because we could not conduct interviews with the 2023 cohort. Most students highly valued their interaction with FLEET scientists, with about 88% of them entering a ranking of 1 or 2. See Figure 1. This outcome is supported in the themes that emerged from the open-ended questions and interview data that are outlined below. Note, the Likert scale inadvertently used only a 4-point scale instead of a 5-point scale. Given we are seeking an opinion, it would have been more appropriate to use a 5-point scale.

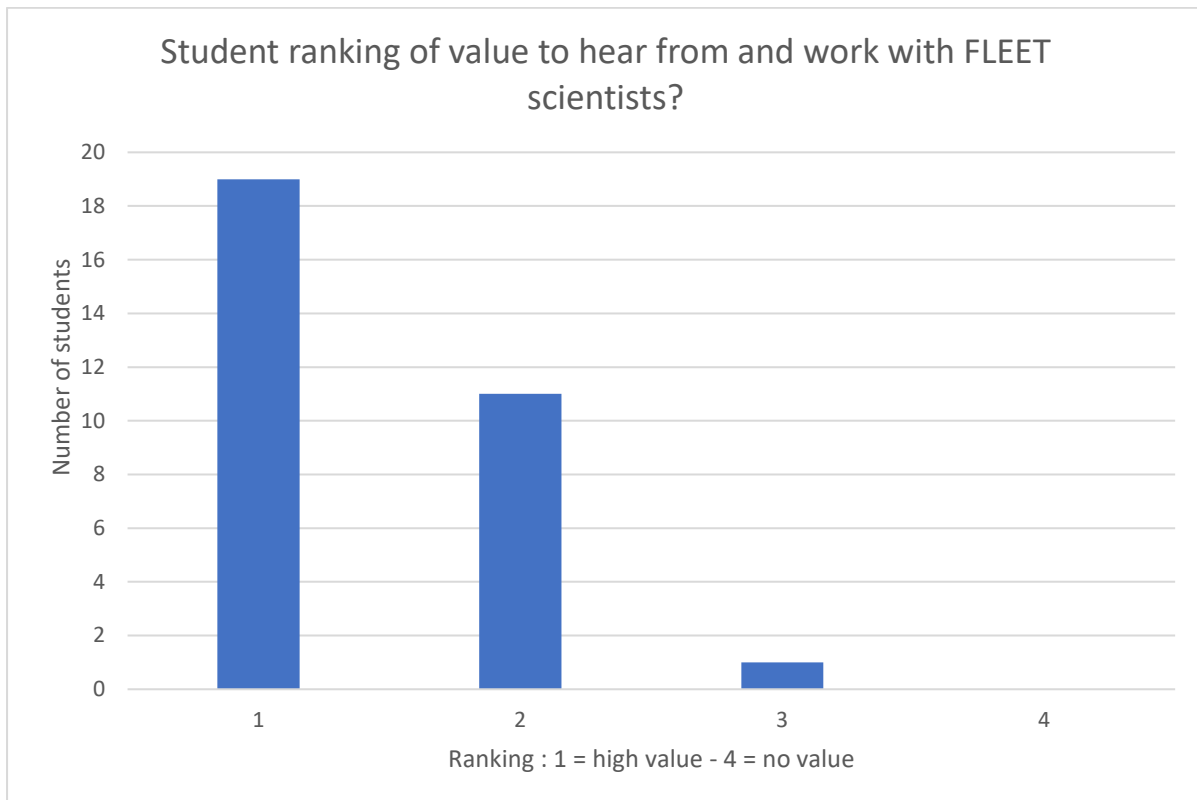


Figure 1. Ranking of how JMSS students in the FLEET unit value hearing from FLEET scientists

Qualitative, open-ended questions

There was a variety of themes over the four years that were evaluated, but three core themes were common to all years:

- The crucial role of FLEET presenters
- Enjoyment of specific topics (some topics were enjoyed more than others)
- Value of hands-on practical components (enjoyed by everyone)



A fourth and largely anecdotal theme that emerged from the interview data was the role of female FLEET presenters in enabling female students to see a place for themselves in physics.

Each of the four core themes are examined below.

FLEET presenters are crucial

As noted above, JMSS students highly valued their engagement with FLEET presenters.

Despite the different questions over the years that were relevant to FLEET presenters, two common sub-themes emerged from them regarding the impact and value of FLEET presenters.

- FLEET presenters made the science real, palpable and valued
- Increased breadth, and depth about physics

FLEET presenters made the science real, palpable and valued

Students got value and inspiration by hearing first-hand personal stories from FLEET presenters about their research, the problem they were trying to solve, the value of that research and their life as scientists. Such stories made physics real and palpable as they received from FLEET presenters a raw, unfiltered insight into cutting-edge physics. FLEET presenters exposed the students to the connection between the theory or facts they learned and its application to real-world problems.

I learnt that they work on solving significant problems together in groups and collaborate with other scientists to come up with innovative solutions.

FLEET has made me consider research, especially in physics, as a potential career through meeting people who work in research and demonstrating that it is possible.

I think it was great to see professionals and people who do what we are learning about as a living, and to also hear from their experiences, it puts everything into perspective

In physics, we are taught a lot about equations and stuff, maybe it is more about seeing it in reality with actual things that have a purpose in everyday life...It has made me see like different areas and a few of them that I was able to go into and see what researchers actually do.

Increased breadth and depth of understanding about career opportunities in physics

FLEET presenters gave students a new and broader perspective on physics as a career and discipline.

I enjoyed how FLEET could be incorporated into many other fields of science which I have previously not known about.

I really enjoyed the presentations by the Monash researchers about the different areas of FLEET and how their work aims to find better solutions to energy efficient technologies.

I learned how diverse the work of physicists could be. The presentation from [presenter] cleared a lot of my confusions on quantum physics.

[I learned about] Their field of science in a more detailed manner which provided a more in-depth experience to their research but also helped me understand and consider that was what I wanted to work as in the future.



It has made me realize that physics is a lot more about understanding a deeper concept of the world around us, and there's a lot more to learn as well as discover.

... and to also hear from their experiences, it puts everything into perspective and broadens the range of options one might have about their future.

It has opened quite a few different careers because seeing the researchers it actually shows us a career that I could pursue and after doing this topic I gained a lot of interest in it.

It has opened my eyes to a lot of new things, like before the FLEET unit I thought physics was, I guess, ...there was astrophysics and then...you throw a ball and you look at the arc it makes, but doing the FLEET unit showed me that there was so much more than that, especially in atomic level physics. I found that really fascinating and it was insightful to learn about...it was so much more than I could have previously known.

With FLEET, it is has really shown how physicists are able to do more than look at how things are modelled, for example, a ball flying through the sky. Through FLEET, I have seen how physicists work in teams and work together to find new stuff and even if they don't find new stuff they are able to use the data to help people do other things. My perspective on what a physicist is really changed during the FLEET unit.

I think it [FLEET unit] gave me a larger perspective on what I could do. I didn't know I could go in and look at 1D and 2D materials [in graphene prac] or cool things like that. I didn't know that was an option, but I do now. From that perspective it has influenced my options because it has broadened my options about what is out there and what I could do.

Enjoyment of specific topics that were unique for students

When asked what they liked most about the unit, students typically stated specific topics they enjoyed. Quantum physics and Binary, Transistors and Boolean Logic were typically the most popular topics.

I liked learning about quantum physics and how diode works

Quantum physics as I have always wanted to learn about [it]

Hands-on learning

Typical of any student workshop FLEET has been involved in, the hands-on activities are always rated high.

[I liked] The presenters and the interactive experiments

Sense of place

The fourth theme that emerged largely from the semi-structured interview and most strongly from the female students was a 'sense of place'. The female students interviewed considered that seeing female FLEET presenters helped them realise there was a place for them in physics. FLEET's female presenters provided inspiration, motivation and agency.

It is more about passion and wanting to do this and them [FLEET presenters] sharing their background stories – it inspired us all and despite our background in physics and life in general, we can grow up and be in this field if we want to and have the passion to do so.

I feel that is what would have happened at my old school and that subjects like psychology, physics, biology were just more male dominated subjects and females shouldn't be in it. I feel personally that with FLEET seeing the female speakers inspired



me more to want to consider this field just because I thought there is a place for females in this field.

They [female FLEET presenters] gave us a kind of inspiration that us females can do something in this field of research and seeing them come and present made me think, well I can do this as well. It is not just a male-dominated industry. The research the girls were doing, they were really interesting and I guess it showed me that I can do it...Before I thought most of the research and more of the thinking work would be done by males and women would not be interested in this field, but when the presenters came I saw that there are a lot of females that are in this research...I was thinking of doing physics and continuing in the field, but I wasn't really sure, but when I the female presenters came, they gave me more hope to continue in this field because there are others there as well.

I really liked it [having female physicists present] because it was someone I could relate to more. Just being able to see someone in that field. But I also liked that their personality trait being there wasn't being female. It was great.

*As reported in the 2022 evaluation report of the FLEET unit, there is supporting evidence in the literature that having a female role model can positively affect female students' inspiration and sense of place in STEM ^(1, 2, 3). There is also research that suggests that gender is less of an influence compared to perceived stereotypes. That is, female (or any gender) students may be less influenced by the gender of their role model and more influenced to pursue specific careers in STEM if their role model fits a more appealing stereotype ⁽⁴⁾.

Discussion

FLEET's objective with the JMSS quantum unit was to contribute to JMSS students' scientific literacy in quantum physics and their understanding of FLEET science. This was to be reflected in learning outcomes, how students value physics and the physical sciences as a career and discipline, their intended participation in STEM subjects in senior high school and through to university, and how FLEET presenters facilitated these objectives, especially for female students.

Literacy

Based on student enjoyment and interest in the unit topics and their descriptions of what they learned ("I liked learning about quantum physics and how a diode works"), students finished the unit with improved scientific literacy relevant to quantum physics.

Two core themes of interest to FLEET that emerged, FLEET presenters are crucial; and There is a place for me, are indicative that FLEET presenters played an essential role in helping students understand the topics, gain a greater breadth and depth of understanding about physics as a career and discipline; they made physics palpable and real and they inspired and motivated them to consider doing further study of physics. Although the theme, There is a place for me, remains anecdotal if confined to the four female JMSS students, it has some rigour when analysed alongside the peer-reviewed and gray literature.

The two core themes of interest to FLEET emerged:

1. FLEET presenters are crucial
2. There is a place for me



FLEET presenters are crucial

Doubtless, the JMSS teachers in the FLEET unit influenced the impact of the FLEET unit, but the evaluation's objective was to understand the impact of the course itself and specifically the impact of the FLEET presenters.

FLEET presenters' crucial role emerged in the survey and interview data. Alongside the experiments or practical components, students valued their engagement with the FLEET presenters as they enabled a deeper and broader understanding of the topics; the discipline of physics and the role of physicists; to see a purpose and value to physics and an awareness of how physics is applied to solve real-world problems. FLEET presenters made physics relevant and palpable. This connection to real physicists and their role is also one of the reasons for students shifting towards a greater likelihood of studying physics or pursuing physics as a career, which is summed up in the following two quotes

It has opened my eyes to a lot of new things, like before the FLEET unit I thought physics was, I guess, ...there was astrophysics and then...you throw a ball and you look at the arc it makes, but doing the FLEET unit showed me that there was so much more than that, especially in atomic level physics. I found that really fascinating and it was insightful to learn about...it was so much more than I could have previously known.

With FLEET, it has really shown how physicists are able to do more than look at how things are modelled, for example, a ball flying through the sky. Through FLEET, I have seen how physicists work in teams and work together to find new stuff and even if they don't find new stuff they are able to use the data to help people do other things. My perspective on what a physicist is really changed during the FLEET unit.

There is a place for me

FLEET deliberately used female researchers in outreach to show that women (and anyone) can do physics. It was intended to be subliminal in that the female members are there as physicists to engage the public and students with FLEET research. They are not there to proactively promote women in STEM or physics. The most important outcome for the JMSS students was that by seeing other women in physics, women that they perceived do important and valued research, they saw a place for themselves in this field. That is, this realisation, exemplified in the quote below, gave them agency – the power or capability to act – and pursue a career in physics if they choose.

They [female FLEET presenters] gave us a kind of inspiration that us females can do something in this field of research and seeing them come and present made me think, well I can do this as well. It is not just a male-dominated industry.

Limitations

John Monash Science School attracts students already interested in science, though not necessarily physics. The unit is also an elective – a topic that students self-select. Therefore, the high level of interest and enjoyment in the unit may largely be because of the self-selected students who are likely to enjoy and get value from it.

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