JMSS-FLEET unit evaluation 2022

This report is an evaluation of the John Monash Science School FLEET unit on future electronics for the year 2022. The report is based on analysis of the 2022 student survey and semi-structured interviews with four JMSS students.

Highlights

- More than 90% of students enjoyed and found the unit interesting
- On average, 90% of students thought that the topics should be kept in future years
- The majority (55%) of students perceive that their experience with the FLEET unit has made them consider studying physics-based subjects in the future
- FLEET presenters are crucial with 97% of students saying it was valuable to hear from and work with FLEET scientists
- There is further evidence that female FLEET presenters enable female students to see a place for them in physics

Overview of the FLEET unit

The FLEET unit introduces the John Monash Science School (JMSS) Year 10 students to quantum physics at an intuitive level (with minimal maths) and expands on this fundamental understanding to explain complex, useful quantum states such as superfluids and topological materials.

JMSS conducts the unit as an elective over one semester. 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 bulk of the unit is taught by JMSS physics teachers with FLEET members providing guest presentations. In 2022, FLEET presentations were a combination of online and in-person. FLEET conducted presentations for the students on the following topics:

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

Evaluation

Each year, the JMSS students who have done the FLEET unit complete a survey to evaluate aspects of the unit. In 2022, 36 students completed the survey. The survey contains quantitative Likert-like scales and open-ended questions. The Likert-like scales used in the following questions assess the specific topics in the unit:

- I found this topic interesting
- I enjoyed this topic
- I found this topic difficult
- This topic was presented in a way I could understand
- I would keep this topic in the course in future years

The following Likert-like questions applied to the unit overall:

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

The open-ended questions are as follows:

- What did you like most about the course?

- What would you change about the course to improve it?
- What did you learn about the FLEET scientists who were involved in the course this year?

In 2022, semi-structured interviews were conducted with four students (two male and two female) who had completed the unit in Semester 1. The four 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?

The two female students were also asked about their experience with FLEET's female presenters to get a better understanding of any impact they might have on women in STEM.

Aims of the evaluation

The survey evaluates student enjoyment of the unit and how they value it. This is examined in this report. For FLEET, a greater emphasis for the evaluation is to increase FLEET's understanding of the following:

- 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.

This evaluation first examines the quantitative Likert-like survey questions, then the open-ended questions. The interview questions are examined alongside the relevant open-ended survey questions. The question about the role of the female presenters is analysed separately.

Results

Results outlined here are summaries of the main findings. Detailed tables and graphs of each of the Likert-like survey questions can be found in Appendix 1. The Likert scales were Agree – Partially agree – Neutral – Partially disagree – Disagree.

Likert-like questions

I found this topic interesting

Students typically found the topics taught in the unit interesting. On average, 96% of students agreed or partially agreed that the topics were interesting. Based on students who selected 'agree', Quantum physics was the topic students found most interesting with 86% of students selecting agree. Topological materials was the topic of least interest with 44% selecting agree, though 88% selected agree or paritally agree.

I enjoyed this topic

Enjoyment reflects interest in the topics and the results for enjoyment of the topic are similar to the topic being interesting. On average 90% of the students agreed or partially agreed they enjoyed the topics. Binary, Transistors and Boolean Logic, and Quantum physics were the two topics students enjoyed most where 72% and 67%of students respectively agreed that they enjoyed these topics. Topological materials was the topic students enjoyed the least where 39% of students agreed that they enjoyed the topic, but 72% agreed or partially agreed they enjoyed the topic.

I found this topic difficult

Students typically did find the topics difficult and their perception of difficulty varied between topics, but as suggested by their their high level of interest and enjoyment, the difficulty of the topics did not affect their interest or enjoyment. For example, Quantum physics and superfluids were the topics students found the most difficult yet both rated highly for enjoyment and interest. On average 61% of students agreed or paritally agreed they found the topics difficult, and 39% of students disagreed or partially disagreed that the topics were difficult.

The topic was presented in a way I could understand

Overall the students thought the topics were taught in a way they could understand. On average, 87% agreed or partially agreed that the topics were taught in a way they could understand. If you look at the agree category in the Likert scale there is some variation across the topics with 72% of students agreeing that the topic, Binary, Transistors and Boolean Logic was presented in a way they could understand. Only 33% of students agreed that the topic, Superfluids was presented in a way they could understand, though this increased to 78% if you include the scale, partially agree.

I would like to keep this topic in future years

On average, 90% of students agreed or partially agreed that the topics should be kept in future years, though with some variation between the topics. Quantum physics and Binary, Transistors and Boolean Logic were the most popular topics with 78% and 75% students respectively agreeing that these two topics should be kept in future years. In comparison, only 42% of students agreed that topological materials should be kept.

Quantitative questions about the FLEET unit

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

The results for this question indicate that the majority (55%) of students perceive that their experience with the FLEET unit has made them consider studying physics-based subjects in the future. About 28% of students were already planning to study these topics in the future. Only a minor proportion (17%) of students perceived the unit had no effect on what subjects they wanted to study in the future. This is a shift in the effect of the unit compared to 2021. In 2021, the distribution between the students that were either already planning to study relevant subjects in the future, or perceived the course had made them consider studying physics or other relevant subjects in the future was approximately the same with about 43% of the students selecting either category. See Table 1 and Figure 1 below.

Table 1. JMSS Year 10 FLEET unit evaluation 2022. 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	**Number of students** (2021 data)
Yes - It has made me consider doing these subjects in the future	20 (15)
I was already planning to pursue study in these fields in the future	10 (19)
No - It has had no effect on what I wanted to do in the future	6 (7)

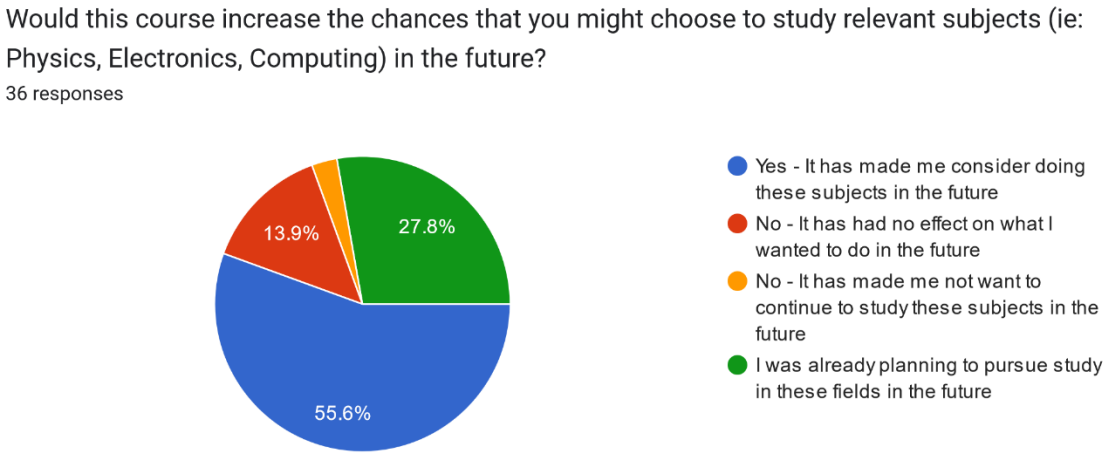

Figure 1. 2022 data

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 will be useful anyway?

Most students (58%) in 2022 thought that most of what they learned in the unit would be useful outside a physics-based career. About 28% of students, however, considered that what they learned would only be somewhat useful or not useful at all. The results did not significantly vary between 2021 and 2022. See Table 2 and Figure 2. Below.

Table 2. JMSS Year 10 FLEET unit evaluation 2022. 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	**Number of students 2022** (2021 data)
Yes - all of it is useful and/or interesting	5 (7)
Yes - most of it was useful and/or interesting	21 (23)
Somewhat - some of the topics were useful and/or interesting but some were not	9 (8)

No - I didn't think the majority of the topics would be useful and/or interesting	1 (3)

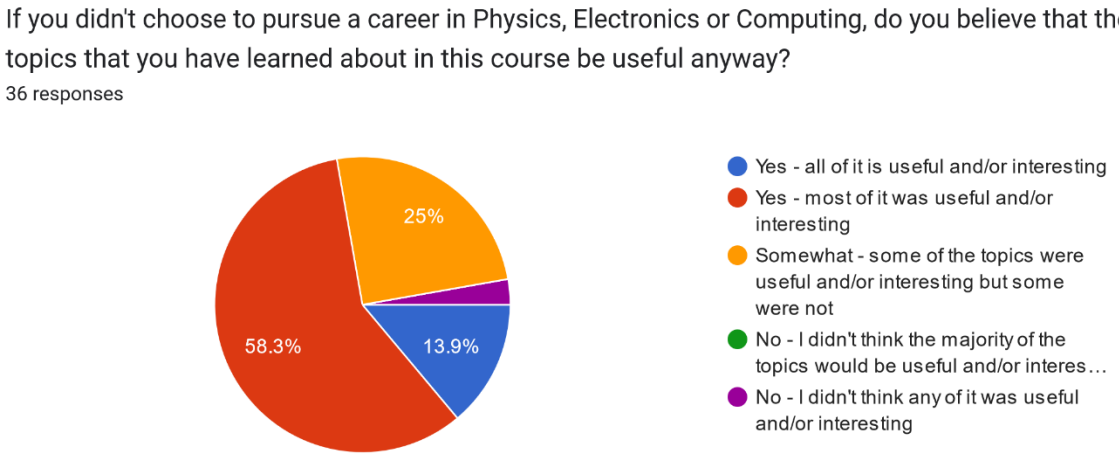

Figure 2. 2022 Data

Qualitative, open-ended questions

What did you like most about the course?

Four broad themes emerged from the students' responses to this question: Specific topics; FLEET presenters; Hands-on; and Lab tours. Each theme is analyzed below.

Specific topics

Students answered that they liked specific topics (N=9). Six students specifically said they liked learning about quantum physics.

> "I liked learning about quantum physics and how diode works"
>
> "Quantum physics as I have always wanted to learn about [it]"

FLEET presenters

Students made 16 positive references to FLEET presenters. Six of these references were direct mentions that they liked the FLEET presenters talking to them or learning about their research.

> "I enjoyed the informative presentations by the Monash alumni [FLEET] about the different topics in FLEET."
>
> "…having scientists come in and talk to us about their research in FLEET"

Other comments reflected what students learned from FLEET presenters and come under the sub-themes of Connections to the real world; Being special; Career direction; and Broader perspective.

Connections to the real world: Six students said they liked learning from FLEET presenters about the cutting-edge physics to develop technologies for real-world problems

> "I really also really enjoyed learning about physics that is relatively new and is being used to develop new technologies."
>
> "Being able to have a first-hand experience into what FLEET holds for the future."
>
> "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 liked the relevance of the topics to real world electronics."

Being special: Students suggested that through the FLEET presenters they felt they were learning physics that others would not until university and that they were getting a unique insight into real physics research unavailable to other students.

> "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"

Broader perspective: One student mentioned they liked how FLEET presenters exposed them to areas of physics they were unaware of.

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

Hands on

Three students responded that what they liked best about the FLEET unit was the hands-on activities/experiments

"[I liked] The presenters and the interactive experiments"

"[I liked] The demonstrations"

Lab tours

A surprising favourite of the course was the tour of FLEET labs. Seven students indicated this was one of their favourite parts of the unit. This was unexpected because it was a short 30-minute tour that involved a quick look at a scanning tunneling microscope lab and a short demonstration of the mobius strip (that didn't work so well because of a flipped magnet that I didn't see).

"I liked going to the FLEET labs and touring around there and looking at the floating superconductors"

"I enjoyed the FLEET labs excursion the most"

What would you change about the course to improve it?

The majority of responses (N=11) to this question suggested that greater interactivity or more experiments would improve the course. The next most dominant theme (N=7) was a perceived need to slow the pace of the course down and cover the topics in greater depth. The general feeling among these students was that the unit covered too many topics, too quickly.

"The structure of the subject is loose and covers too many topics over a short period of time"

"Maybe spend more time on new things so it's easier to understand them."

This reflects responses from two students that suggested there needs to be better linkage between the topics

"Implementing a course timetable and links between separate subjects throughout the year so the elective is not fast paced and disjointed."

The only other strong theme to emerge was a suggestion from three students for the FLEET presenters to give in-person presentations.

Please elaborate on your answer to the question above about the usefulness of the topics we have learned about.

The majority of the responses fit under the core theme, Finding relevance to other sciences/science careers. Only one other strong theme emerged: Finding value in the knowledge. Each theme is analysed below.

Most responses (N=9) were positive in their description saying the topics would be useful in other areas of science or to their chosen career in science.

"I feel like most of these areas are useful in most areas of science."

A small number of responses (N=3) were negative about this usefulness of the topics outside of physics or a science career

"The subjects were useful if pursuing a physics career, however, if not they were not very useful."

Three of the responses thought only certain topics would be useful to them in the future, though neither described whether that future was in science or life in general.

> "Some things such as kinetic energy and learning about transistors can be used in the future"

There were five responses that emerged under the theme, Finding value in the knowledge. The responses implied that students considered that what they learned in this topic would be useful to their lives regardless of their career path.

> "The topics applies to the real world. Knowing how the technology we use everyday is useful, understanding that metals conduct electricity and non-metals do not is useful to avoid being electrocuted."

> "I think it is nice to know, as it can provide insight to future technologies and what I may see in the future in terms of technologies."

What did you learn about the FLEET scientists who were involved in the course this year?

The responses to this question were often unrelated to what students learned about the FLEET presenters and more about what they learned from them. I used both types of response in the analysis of the question. The following five themes emerged from the responses to this question: Being a scientist; Passionate and expert; Breadth and depth; Valued research; and Inspiration. Overall, 97% of students thought it was valuable to hear from and work with FLEET scientists. See Figure 3 below. The five themes are examined in more detail below.

Being a scientist

The majority of comments (N=8) were based on what students learned about being a scientist that they were previously unaware of. This included, the collaborative environment scientists work in, the time and effort required, the rigour required to ensure experiments are valid, and that the work is not all monotonous.

> "I learned a lot about their experience and how much time and effort goes to make experiments perfect."

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

Passionate and expert

There were seven comments that indicated students' appreciation for FLEET presenters' expertise in their role and their passion for what they do.

> "I found it really helpful to learn from someone who is very knowledgeable in the field we were discussing."

> "The main thing I learnt was that they are all very passionate about their jobs and find it rewarding."

> "They all had a very deep understanding of their jobs and content."

Breadth and depth

Five comments reflected students' new perspective on the depth and breadth of scientific disciplines out there, at least in physics.

> "[I] Learned more in-depth about the fields they work in, as well more opportunities in fields I was unaware of."
>
> "I learned how diverse the work of physicists could be. The presentation from Dr Menuicci cleared a lot of my confusions on quantum physics."

Valued research

Three comments implied the respondents placed a value on the FLEET research.

> "The research they [FLEET presenters] conduct, truly is important for future development of sustainability."
>
> "From the many scientists involved in this course, I learnt about how their research was a key aspect towards lower energy technologies."

Inspiration

Two students said they received some form of inspiration from the FLEET presenters to pursue a career in physics.

> "The research they are working on is very interesting and it made me think about pursuing in this field."
>
> "[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."

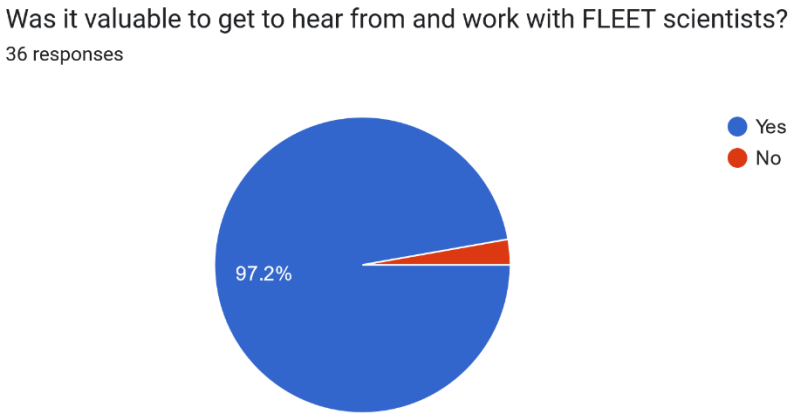

Figure 3. 2022 data

Student interviews

Four JMSS students were interviewed during a school lunch break. They were interviewed two at a time. Four core themes emerged from the 2022 interview data that were also themes that emerged from the 2021 student interview data. The four themes were the following:

- Deeper understanding
- Opportunities, untapped potential, inspiration
- First-hand, cutting edge, real, palpable
- A place for me

I describe each of the themes below and draw on relevant 2022 survey data and 2021 interview data to support the 2022 themes. There is a strong correlation between a majority of the 2021 and 2022 student interview responses. There were some responses in the 2022 student interview data that reflected the additional themes in the 2021 data, but the 2022 responses were insufficient to emerge as themes. This may be because there were seven students interviewed in 2021, which enabled a wider range of perspectives. Students are designated S1-4.

2022 themes

Deeper understanding

The interview data supports the survey data that the FLEET unit gave students a greater breadth and depth to their understanding of physics as a discipline and the diverse roles of physicists. Some of this understanding came from the visit to the FLEET labs, which reflects the survey data where seven students indicated this was one of their favourite parts of the unit.

> S2. 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.

> S3. I have always enjoyed the subject [physics]. I thought it was really cool to see what people are actually doing in labs, because I know we get taught all this stuff about physics and how it works, but never really how people go out and do research and how jobs are supported in physics and how they look to continue making materials.

What is a physicist

> S3. 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.

S4's experience in the FLEET unit helped break down their stereotypical perspective of a physicist

> S4. My perspective was pretty much from the big bang theory – people standing at a white board and writing down maths equations.

S1 recalled their visit to the FLEET labs that further facilitated a connection between physics and solving real-world problems.

> S1. When we came for the incursion to FLEET, we saw superfluids and the mobius strip and how they [superfluids] have no viscosity and how they can help the future and stuff. I am interested in the quantum level and how we can make that more efficient and how it can help us in the future

Opportunities, untapped potential, inspiration

Students' greater understanding of the breadth and depth of physics as a discipline exposed them to greater opportunities in the field of physics and provided inspiration for different career paths they had not been aware of or considered before their experience in the FLEET unit. While the students in this unit were typically already interested in science and physics, their exposure to the diverse opportunities they

learned about in the FLEET unit helped to further clarify their career pathways, which for some, now included physics. This supports the survey data that found 55% of students perceive that their experience with the FLEET unit has made them consider studying physics-based subjects in the future.

All the students interviewed said that their FLEET unit experience made them rethink their ideas about physics because they now saw new opportunities and potential in career paths they were previously unaware of.

> S2. Before we started the FLEET unit, I was interested in mathematics, chemistry, biology and stuff like that, but during and after FLEET I have become more interested in physics – like nuclear physics, etc has been included in my career ideas now…I had not previously known a lot about physics and I think with the FLEET unit there is a lot more to explore that I could be interested in. I think it is a possibility for me to now take up more subjects in physics and explore more of that and incorporate that into a uni course or career because I have found stuff that I am more interested in that I didn't know about before.

> S3 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.

S1 has always considered computing as a career, but the FLEET unit broadened her understanding of the options in this space and she is now interested in following a research or materials engineering path in the area of quantum computing.

> S1. It [FLEET unit] all really opened my eyes to a broader field and research. After that I started looking into computing more…more in the engineering computing field, more like inventing stuff for computers, like what you guys (FLEET) are working on.

First-hand, cutting edge, real, palpable

The FLEET unit helped students realize that physics can be applied to solve real-world problems. Their exposure to FLEET presenters and their research grounded their otherwise esoteric and abstract learning and understanding of physics. The FLEET unit enabled the students to see a purpose to what they were learning and they became aware that there was something real and tangible to what physicists do. This reflects the theme, *Connections to the real world,* that emerged in the open-ended survey questions where six students said they liked learning from FLEET presenters about the cutting-edge physics to develop technologies for real-world problems. It also reflects the 2021 students' experience with FLEET presenters where, alongside gaining a deeper understanding of the discipline and value of physics from FLEET presenters, the presenters were the unfiltered stories, the raw reality of life as a physicist that they can't get from text book and normal physics lesson.

> "Both our teachers have a lot of expertise in these areas already, but having someone who is currently doing research on this topic gives a deeper insight because I feel like – as I said they are doing their research on this so learning about their research from them it feels like that whatever we are learning is unfiltered." 2021 student.

While there is likely a deliberate connection to real-world problems in regular science subjects, including physics, the student data suggests it appears to be more palpable when it comes from engagement with a real scientist telling stories about how they apply these abstract/esoteric concepts to solve real-world problems that students can relate to such as climate change and the need to reduce energy consumption.

> S4. 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.

> S3. We had a presenter talk on laser cooling…It was a cool opportunity to see the people that are actually putting the things we are learning in class into action and get more results, but also how they plan to continue and further the studies in that areas. It was cool to meet those that actually done it.

FLEET presenters were the students' crucial first-hand connection to what they perceived as the cutting-edge, valued and tangible outcomes of physics research. S1, 2 and 4 relate their experience with FLEET presenters during the graphene extraction practical.

> S4. We were learning about the 1D materials and it was really clear how they were useful and I could really clearly see why they were important and useful for people.

> S2. The FLEET presenters we had contact with was an insightful opportunity to learn more about their individual areas…I think everything is easier to learn when you hear it from someone who really knows what they are talking about…and you can ask a FLEET presenter questions and you can't ask a book questions – they have a lot of insight to offer that I can't get by just reading something.

> S1. I remember how they [FLEET presenters] were really passionate about it and you could see how they really enjoyed what they were doing, that is what made us more engaged, knowing that they are so interested in this and like doing it.

A place for me in physics

This theme relates to the two female students' experience with the female FLEET presenters used in the FLEET unit. I asked the students to recall their experience with the female FLEET presenters. This year, I had to ask this question specifically. The female students interviewed in 2021 discussed their thoughts on this without the need for prompting. Regardless, the reflections of the two female students from 2022 on this question mirror the responses from the female students in 2021: Students found inspiration from the female presenters to follow their own interests in science; there was a realization that females were doing physics and that they too could do this; and there was a place for them in this field, should they choose.

> S1. 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.

S4's response reflects the response from S1, but she also made the point that she appreciated that FLEET female physicists were there as physicists, who happen to be female, rather than being there as female physicists. FLEET has deliberately used female physicists this way, but this is the first student to have considered it from this perspective. The caveat here is that this is my interpretation of the S4's response. I did not get the opportunity to clarify whether this is what S4 meant.

> S4. 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.

The following two quotes from 2021 female students reflect those from 2022

> "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 and 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."

There is some supporting evidence in the literature that having a female role model can positively affect female students' inspirations and sense of place in STEM [1, 2, 3], but 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 – what it all means

With only some exceptions noted below, the 2022 data is comparable to the 2020-21 data. I first distil the quantitative survey data and examine the points of difference between the 2020-21 and 2022 data. I then focus on two core themes of interest to FLEET that emerged: FLEET presenters are crucial; and There is a place for me. The theme, FLEET presenters are crucial brings together many elements of the survey and interview data that all point to the valuable role FLEET presenters had in in helping the teachers facilitate students increased breadth and depth of understanding of the discipline of physics and the role of physicists. The theme, there is a place for me, remains anecdotal if confined to the four female JMSS students, but has some rigour when analyzed alongside the peer-reviewed and gray literature*.

Enjoyable, interesting and valuable

Students enjoyed the FLEET unit and found it unit interesting. To varying extents, students found the topics difficult, but this did not detract from their enjoyment and interest in those topics.

The majority of students agreed or partially agreed the topics were taught in an understandable way. There was, however, some variance when you examine the 'strongly agree' option only. For example, only 33% of students strongly agreed that the topic, Superfluids, was taught in an understandable way. This might suggest there is scope to re-examine the content of the topic, though we lack an understanding of what made it difficult for students to understand.

Regardless, on average, 90% of students agreed or partially agreed that the FLEET unit topics should be kept in future years, though there was with some variation between the topics. Quantum physics and Binary, Transistors and Boolean Logic were the most popular topics with 78% and 75% students respectively agreeing that these two topics should be kept in future years. In comparison, only 42% of students agreed that topological materials should be kept.

Similar to the 2020-21 data, a small majority of students thought that most of what they learned in the unit was of value regardless of their career path.

Points of difference

A key point of difference between the 2022 and 2020-21 data occurred with the question, Would this course increase the chances that you might choose to study relevant subjects? Compared to the 2020-21 data, there was a greater number of students (20 compared to 15) that considered that the FLEET unit had increased their chances they would study relevant subjects in the future. While this is encouraging, one would need more years of data to know if this was a trend.

While there remained a call for greater hands-on activities in 2022, a different theme to emerge this year was a perception that the pace of the course was too fast and students wanted the unit to slow down and the topics covered in more depth. This is something to consider about the nature of the elective: It is a taster of a variety of novel physics to broaden students understanding of what physics is, or should there be a greater focus on learning few topics in greater depth. Student expectations and desires are likely to differ between cohorts and this is the perception of one cohort only. Again, one would need more years of data to know if this was a consistent perception.

FLEET presenters are crucial

In support of the 2020-21 findings, students noted in the survey that what they enjoyed most about the course were the experiments or practical components, lab tours and engagement with the FLEET presenters. This strongly reflects the student interview data that found FLEET presenters, through their engagement with students in the practical sessions and lab tours, gave students a deeper and broader understanding of the discipline of physics, and the role of a physicists. Their engagement with FLEET presenters in the practical sessions and lab tours also enabled them to see a purpose and value to physics. Students became aware 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.

For example, despite the short duration of the FLEET lab tour, the student interview and survey data suggests that some of the reason the popularity of the tour was it further enabled student insight into the real-world problems that physicists work on, and it helped break down the stereotype of physicists working at whiteboards doing equations. On the lab tours, students met FLEET researchers that showed students the Scanning Tunnelling microscopes they use to study 2D materials to be used to develop energy-efficient digital technologies. There were no equations, and no whiteboards and there was a tangible and palpable connection to real world problems.

> S4. 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.
>
> S3 I think it 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.

There is a place for me

FLEET deliberately uses female researchers in outreach to show that women (and anyone) can do physics. It is intended to be subliminal in that the female members are there as physicists to engage the public with FLEET research. They are not there to proactively promote women in STEM or physics. The most important outcome of this for the JMSS students is that just by seeing other women in physics and that they do important and valued research, they see a place for themselves in this field, if they choose.

> S1. 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.

There are multiple factors that can influence girls' participation in STEM and physics and there are some further interesting factors to tease out in this data, for example the level of influence of female role models versus positive stereotypes. The further limitation to the findings in this

report remains the small sample size, but FLEET will continue to survey the JMSS students each year to understand the role of female FLEET presenters.

References

1. González-Pérez Susana, Mateos de Cabo Ruth, Sáinz Milagros (2020). Girls in STEM: Is It a Female Role-Model Thing? *Frontiers in Psych*ology 11. DOI=10.3389/fpsyg.2020.02204 URL=https://www.frontiersin.org/articles/10.3389/fpsyg.2020.02204

2. Sivan Isaacson, Lonia Friedlander, Chen Meged, Shiran Havivi, Aviv Lee Cohen-Zada, Inbal Ronay, D.G. Blumberg, Shimrit Maman (2020). She Space: A multi-disciplinary, project-based learning program for high school girls. *Acta Astronautica*, 168, pp 155-163. https://doi.org/10.1016/j.actaastro.2019.12.005.
3. Vivian, R; Robertson, L; Richards M (2020) The GiST Girls in STEM toolkit. *Classroom strategies for inclusive STEM learning environments.* Education Services Australia Limited
4. Cheryan, S; Drury, BJ; Vichayapai, M (2013). Enduring Influence of Stereotypical Computer Science Role Models on Women's Academic Aspirations**.** *Pyschology of women quarterly* 3791 pp 72-79 DOI: 10.1177/0361684312459328

Appendix 1 Survey data for FLEET unit 2020 and 2021

The following

Figure 1. Survey questions for the topic, Conductors, Insulators and Semi-conductors

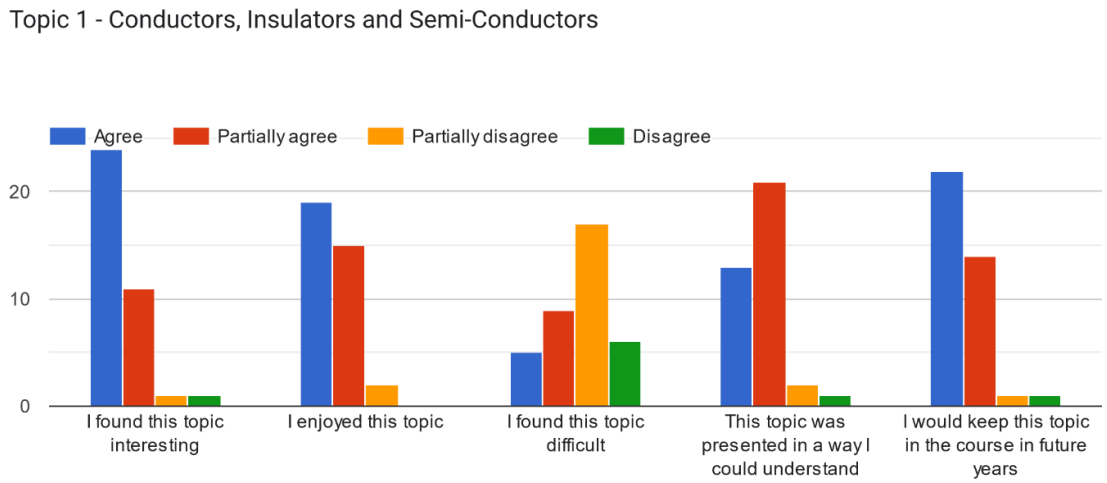

Figure 2. Survey questions for the topic, Binary, Transistors and Boolean logic

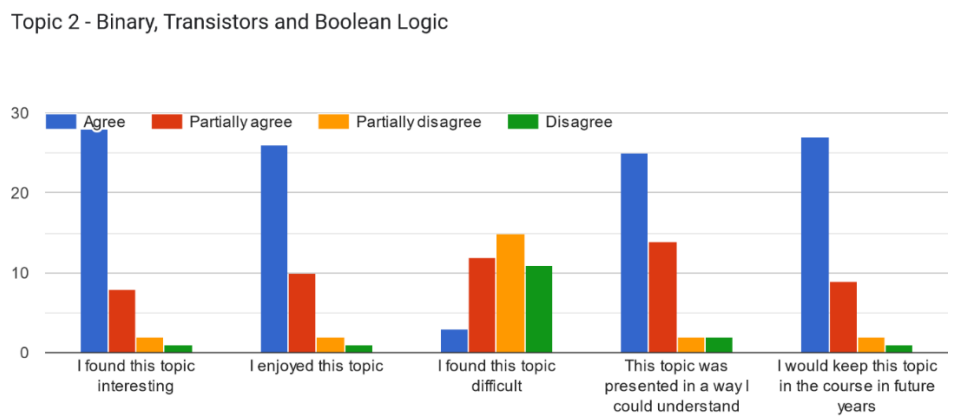

Figure 3. Survey questions for the topic, Momentum and kinetic energy

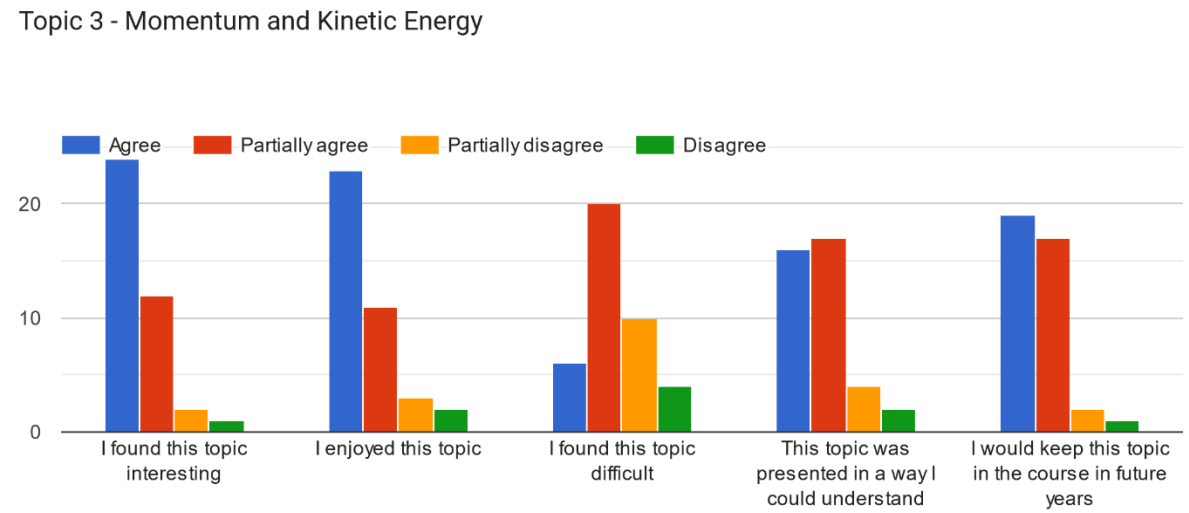

Figure 4. Survey questions for the topic, Quantum physics

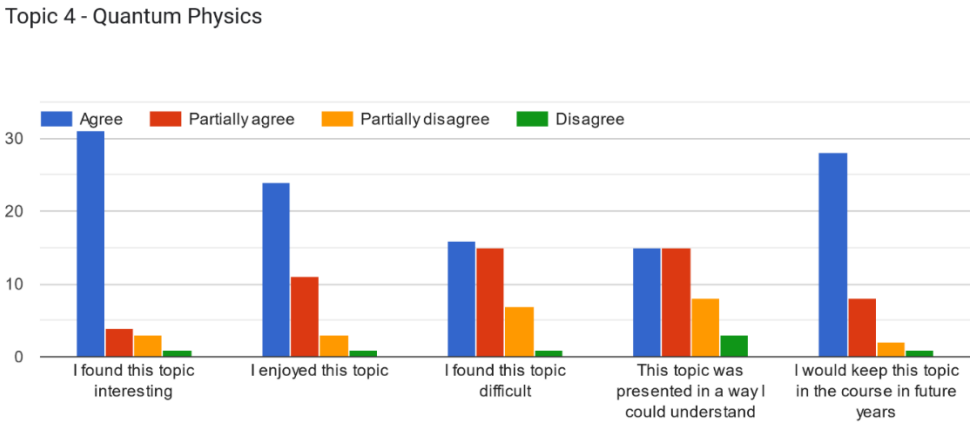

Figure 5. Survey questions for the topic, Topological materials

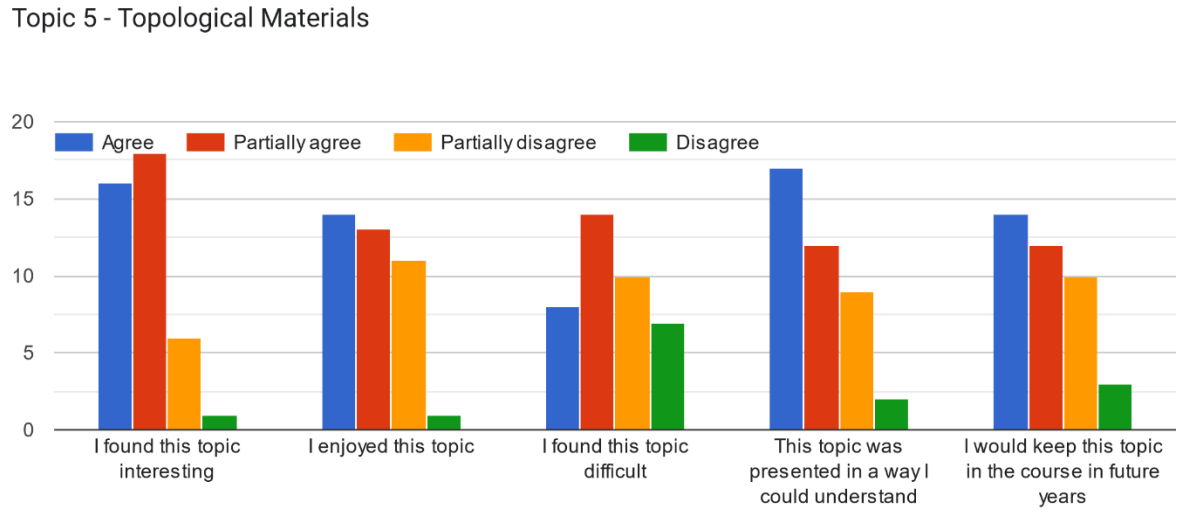

Figure6. Survey questions for the topic, Superfluids and excitons