JMSS-FLEET unit evaluation 2020 and 2021

This report is an evaluation of the John Monash Science School FLEET unit on future electronics for the years 2020 and 2021. The evaluation is an analysis of surveys used in both years and a semi-structured interview of seven students from the 2021 unit.

Overview of the FLEET unit

The FLEET unit introduces 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 conducted by JMSS physics teachers. In the 2020 and 2021 units, 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 (virtual).

Evaluation

Each year, the JMSS students who have done the FLEET unit complete a survey to evaluate aspects of the unit. In 2020, 35 students completed the survey. In 2021, 41 students completed the survey. The survey contains quantitative Likert-like scales and open-ended questions. The Likert-like scales assess the following questions:

- 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
- 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?

Because of COVID restrictions, the unit was conducted online in 2020 and 2021. This restricted the practical or experimental activities that could occur.

In 2021, semi-structured interviews were conducted with seven students in the last week of the unit. The seven 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?

Aims of the evaluation

The evaluation intends to increase FLEET's understanding of the following:
The effect of the unit on student perceptions of the value of physics as a discipline
The effect of the unit 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 achievement of the above aims.

FLEET deliberately uses female presenters as much as possible in an attempt to raise awareness of women in physics and STEM generally. While not the focus of this evaluation, two of the students interviewed were female. Their conversation is suggestive that the female FLEET presenters had an effect on the students' perception of physics and their sense of place in a physics-based career. For this reason, the role of FLEET presenters is considered in this context.

The evaluation examines first the quantitative Likert-like survey questions, then the open-ended questions. The qualitative interview questions are examined alongside the relevant open-ended survey question: What did you learn about the FLEET scientists who were involved in the course this year?

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

Likert-like questions

I found this topic interesting

In both years students typically found the topics taught in the unit interesting. While the differences between each topic are subtle, the most interesting topic for students in 2020 was quantum physics. In 2021, these topics were conductors/semi-conductors and transistors/Boolean logic.

Depending on the topic, between 85%-100% of students agreed or partially that the unit topics were interesting. In 2021, this difference ranged between 80-92%.

I enjoyed this topic

Enjoyment reflects interest in the topics and the results are similar for both years.
In 2020, depending on the topic, between 82%-97% of students agreed or partially agreed that the topics were enjoyable. In 2021 this difference ranged between 80-97%.

I found this topic difficult

In 2020 and 2021 students typically did find some aspects of the topics difficult and their perception of difficulty varied between topics, but as noted above, difficult typically appear to not deter their interest or enjoyment.

In 2020, the topics students found most difficult were quantum physics, topological materials and superfluids/excitons. In 2021, only quantum physics was considered relatively difficult.

In 2020, there was a range between topics of 28-71% of students who agreed or partially agreed that the topics were difficult. In 2021 the range between topics was 31-73%.

The topic was presented in a way I could understand
Overall the students thought the topics were taught in a way they could understand.

In 2020, between 80-94% of students agreed or partially agreed that the topics were presented in a way they could understand. In 2021 that range was 65-90%. The anomaly compared to 2020 was the topic, quantum physics, where 34% of students disagreed or partially disagreed that the topics was taught in a way they could understand. This figure for quantum physics was only 8% in 2020.

I would like to keep this topic in future years
In 2020, between 85-100% of students agreed or partially agreed that the topics should be kept. In 2021, this range was 78-90%.

Would this course increase the chances that you might choose to study relevant subjects in the future?
The results for this question are similar for 2020 and 2021. Only a minor proportion of students perceived the unit had no effect on what subjects they wanted to study in the future. There was an even distribution between the remaining students that were either already planning to study relevant subjects in the future, or perceived the course had indeed made them consider studying physics or other relevant subjects in the future. See Table 1.

Table 1. JMSS Year 10 FLEET unit evaluation 2020. 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 2020 (N=35)**	**Number 2021 (N=41)**
Yes - It has made me consider doing these subjects in the future	16	15
I was already planning to pursue study in these fields in the future	17	19
No - It has had no effect on what I wanted to do in the future	2	7

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?

Again, the results did not significantly vary between 2020 and 2021. Most students thought that most of what they learned in the unit would be useful outside a physics-based career. About 25% of students, however, considered that what they learned would only be somewhat useful or not useful at all. See Table 2.

Table 2. JMSS Year 10 FLEET unit evaluation 2020. 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 2020 (N=35)	Number of students 2021 (N=41)
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	8	8
No - I didn't think the majority of the topics would be useful and/or interesting	1	3

Open-ended questions

What did you like most about the course?

The same themes emerged from the 2020 and 2021 analysis of the answers to this question. The core themes to emerge are in Table 3. The dominant themes that reflect what students liked most about the unit are their enjoyment of the FLEET speakers and specific topics. Students also considered the practical activities enjoyable, despite the ability to conduct them being restricted during remote learning. Themes of note that reflect themes that emerged in the interview data (see below), are the breadth of topics covered (students appeared to be unaware that the discipline of physics was so broad and diverse); the connection they could make between what they learned and how it applied to solve real-world problems; and the perception that they were participating in something unique by learning physics that no other secondary student was learning.

Table 3. JMSS Year 10 FLEET unit evaluation 2020. Student question: What do you like most about the course?

What students liked	**Number of students 2020 (N=35)**	**Number of students 2021 (N=41)**
Students enjoyed the FLEET speakers	12	7
Students who selected a specific topic they enjoyed	11	9
Students enjoyed the breadth of topics covered	5	3
Students enjoyed the hands-on activities and assignments	4	2
Students enjoyed learning how the physics is applied to technology development	4	4
Students perceived the unit was unique and that they were learning stuff no other student would be learning	2	2

What would you change about the course to improve it?

The vast majority of students in 2020 expressed a desire for more hands-on activities and experimental work, though they typically acknowledged the COVID made this difficult. This was reflected in the 2021 cohort, but to a lesser extent.

> "I understand that we were limited due to spending more time online, but in order to improve the course, I might suggest including an experiment or two so that students can understand a concept and show their understanding by doing the experiment."

This student requested hands-on activities with a tangible outcome

> "Have a physical project like build something with transistors."

In 2020, two students thought a more effective explanation of the concepts was needed to help them understand the topic.

In 2021 there was a suggestion among five students for some form of assessment to help reinforce what they had learned. Typically, this suggestion called for a short assessment or quiz at the end of each topic.

> "I would add end-of-topic reviews to ensure that I can remember what we learn."

> "Conduct quizzes for every topic so that we revise thoroughly and remember more content"

> "Have small exercises to help students remember the material more easily."

What did you learn about the FLEET scientists who were involved in the course this year?
This question combines the analysis of the survey data and the semi-structured interviews of the seven students from the 2021 cohort. The survey data is analysed first, followed by the semi-structured interview data.

Survey question results
A survey question asked the following question that required a yes/no response:
Was it valuable to get to hear from and work with FLEET scientists?
2020 (N=35): 35 students said YES to this question
2021 (N=41): 39 said YES; 2 said NO

The survey asked the open-ended question, What did you learn about the FLEET scientists who were involved in the course this year? The same themes emerged in 2020 and 2021 survey data with similar numbers attributed to each theme in both years.

The following core themes emerged in 2020 and 2021 survey data:

1. Careers
2. First-hand, cutting-edge, real, palpable
3. FLEET intelligence
4. FLEET passion, enjoyment
5. Breadth of physics
6. Learning

The first four themes dominated in 2020 and 2021 accounting for approximately 84% of the student responses. The last two themes, Breadth of physics and Learning, together account for approximately 14% of the student responses, which is an effect considered significant enough to be mentioned in this report. The remaining 2% of responses were varied and not sufficiently significant to emerge as a theme. I outline the meaning of each theme below with student quotes to support and reflect the meaning.

1. Careers

Students learned from FLEET presenters what it is like to be a physicist. Students indicated that they learned about FLEET presenters' individual research, how they conduct that research, the purpose of that research and the variety of research that they conduct. They learned about the many different components to a researcher's job and they increased their awareness of the different career opportunities within physics.

"I learnt how vast the area of FLEET is and how many fields we could get into in the future."

"I learned that the field of FLEET is quite big, despite it being a specific field of science. There are many components and jobs which compose this field and it really opened my eyes to the many possible job careers."

"I learnt a lot about outside school, like labs and what you do as a scientist."

2. First-hand, cutting-edge, real, palpable

This theme reflects what emerged in the interviews with seven of the year 10 students in 2021. The interview data described below adds greater depth to this theme. This theme reflects the value and inspiration students got from hearing FLEET presenters' personal stories about their research, the problems they were trying to solve, and the value of that research. Such stories made physics real and palpable as they received the first-hand, raw, unfiltered insight into cutting-edge physics. FLEET presenters exposed for the students the connection between what they learned and its application to real-world problems.

"…I realised that what they're [FLEET] doing can be quite complicated as the field is pretty new and that some concepts/topics, such as cold atoms for example, would be seem to be unrelated to electronics but actually play a key role in developing low energy technology in the future."

"It was wonderful seeing how what we learned was implemented into the FLEET community."

"It was also interesting to see the applications in real life rather than just what was taught in class."

"I learnt about the fields they specialise in and how their particular field of study relates back to the creation of electronics."

3. FLEET intelligence

Students perceived FLEET presenters to be intelligent.

"They are smart."

"They're smart and very knowledgeable about their specific fields of study."

4. FLEET passion, enjoyment

Students noted FLEET presenters were passionate about their research and enjoyed their jobs and teaching the students.

"It was understandable that they are keen on what they research and enjoy their career in Fleet."

"They are very dedicated to revolutionising the field of computing."

"FLEET Scientists are passionate in their work and seemed to enjoy teaching us about what they did."

5. Breadth of physics

This theme reflects what emerged in the survey question, what did you like most about the course (see Table 3.) and what emerged in the semi-structured interview described below. FLEET presenters appeared to increase student awareness of the diversity of physics research generally and within FLEET itself.

> "I learned many things about many different topics, all which were very eye opening"
>
> "I learned that the field of FLEET is quite big, despite it being a specific field of science. There are many components and jobs which compose this field…"

6. Learning

Students noted that they learned from FLEET presenters, either new physics they were unaware of or clarification of physics that had already covered with the teachers in the unit.

> "About cooling atoms and quantum computers."
>
> "I learnt many things, however the quantum computing webinar stood out as I was confused but through the webinar I have a better understanding."

Semi-structured interviews

The seven 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 path?
2. Tell me about your thoughts on the value of using FLEET scientists to help present the unit?

The following themes emerged from the interviews:

1. Prior interest in physics – was going to do it anyway
2. Opportunities, untapped potential, inspiration
3. First-hand, cutting edge, real, palpable
4. Deeper understanding
5. A place for me
6. Facilitating Sci Comm

I have described the interview themes below and supported them with student quotes.

Interview Themes

Below are outlined the main themes to emerge from the interview of the seven JMSS year 10 students that were in their last week of the unit.

1. Prior interest in physics – was going to do it anyway

All of the students interviewed already enjoyed physics and five of the seven students interviewed had intended to study physics anyway. Despite this, the FLEET unit broadened their understanding and perception of physics, and for some reinforced their interest in the subject.

> "It [the unit] has been useful in helping me know more about what I want to follow… the way [the topics] were taught were a lot easier to grasp and that really helped me to understand the things I wanted to do with the things I learned and how I wanted to continue learning them."

> "I do like physics and I have done since I was introduced to it. I guess the unit just reinforced that."

2. Opportunities, untapped potential, inspiration

All students interviewed stated that the course exposed them to a breadth of physics sub-disciplines that they were unaware of. From this they saw, to varying extents, new opportunities, new interests and potential in physics as a discipline. The motivations to pursue physics differed, but the inspirations were apparent for students already intending to study physics and those still undecided. For those already interested or intending to pursue a career that involved physics, the unit reinforced or clarified their decision to study physics in VCE. FLEET presenters were a crucial component of this inspiration and motivation.

> "FLEET [unit] allowed me to explore physics more and realise there was more to it than nuclear physics and the [FLEET] people make is sound an interesting subject and that there is a lot that goes into it as well – wave particle duality, Boolean logic – there are different sub-branches of physics that I could explore and that was great because I could finally get to explore physics and see if I like the subject or not, which I did."

New opportunities – untapped potential

> "Originally I wanted to study civil engineering and computer science, but after this course it gave me insight into what could possibly be the future of computing, in my time – and quantum computing"

Inspiration

> "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 was actually a very useful unit because I had been tossing up doing physics in VCE over the last couple of weeks and this is kind of sealing the deal for me because we have done a bit more extended stuff into the quantum world, which is useful"

Reinforcement

> "I thought I would take this elective to learn more about the electronics so it has been great to learn about different topics that I wouldn't otherwise have learned about. It has definitely reinforced that I want to work in this field of physics and engineering."

3. First-hand, cutting edge, real, palpable

Students got value and inspiration by hearing personal stories first hand from FLEET presenters about their research, the problem they were trying to solve, the value of that research and their life as a scientist. Such stories made physics real and palpable as they received from FLEET presenters a first-hand, raw, unfiltered insight into cutting-edge physics. FLEET presenters exposed for the students the connection between the theory or facts they learned and its application to real-world problems. Examples of how physics is applied in the real world is doubtless integrated into regular science subjects, but the students in this interview sample appeared to find it more relatable when real scientists talk with them about their research.

> "Because science is such a fast-paced field that …and the information we are getting is from researchers studying that field rather than possibly outdated information."

> "I think that link at the start of the course to the environment and energy consumption has opened up a really good pathway for me because I am traditionally into environmental science, but after looking at all this physics, has made me realize it isn't just Earth and [unclear] apply earth and physical science, I can also go into this technology route to link these two areas – the physics and environmental science."

Linked to real problems

> "This was real-life scenarios and how it is studied in university, you see how the concept is applied and how it relates back to FLEET again."

4. Deeper understanding

Students perceived the FLEET unit gave them a deeper understanding of physics itself – the depth, breadth and value of the discipline. This is linked to first-hand, cutting edge where much of that deeper understanding came from FLEET researchers telling stories about their research and exposing students to the research problems they are trying to solve, and the latest physics they are working on to solve them.

> "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."

5. A place for me

By making physics real, palpable and inclusive, FLEET presenters made students realize there was a place, a purpose, or a career in physics for them if they wanted it, and that they could achieve something in this field.

> "Originally, I wanted to study civil engineering and computer science, but after this course it gave me insight into what could possibly be the future of computing, in my time…it [the quantum computing topic] gave me an idea of what could possibly happen when I am in university and not in a few hundred years."

Inspiration from STEM women

This sense of place appeared strongest in the two female students interviewed. These students enjoyed seeing female FLEET presenters to help them realize that there was a place for them in physics.

> "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."

6. Facilitating Science Communication

While likely inclined toward an interest in science communication beforehand (as one student said, he liked filmmaking and is inspired by Prof. Brian Cox and Derek Mueller), FLEET presenters facilitated two students' interest in science communication by showing them an alternative way to explain and present science, a way that was, for them, easier to understand. To some extent, it gave them some inspiration and food for thought about the potential of science communication as a career path or how they might combine it with a career in science and physics itself.

> "I feel this is another way this course has helped because we have done assignments about science communication that has not only helped us get a better understanding of the topic but a better understanding of how to convey that topic also."

> "I think this [unit] actually pushed me into the science communication area because I loved seeing all those presentations and what they are doing well – what I want to do in the future."

Discussion – what it all means

Interesting enjoyable and useful

Students typically enjoyed and were interested in the topics. Despite a lot of students finding some topics difficult this did not detract from their enjoyment and interest in the unit.

The FLEET unit made a significant proportion of students consider doing physics as a subject in the future. For the students already planning to do physics, the interview data suggests the unit helped reinforce that decision. Regardless of their choice of whether to pursue physics or not, students considered a lot of what they learned in the unit to be useful to their studies and to their lives outside their study or careers, though a significant minority of students struggled to consider how such knowledge would be useful outside a physics-based career.

Hands-on experiment

Students enjoyed this aspect of the unit despite the reduced capacity to run them during remote learning. There was a strong call to include more time for experimental or practical work. With the return to in-class learning in 2022, and therefore the opportunity to reinstate the missing practical components of the unit, it remains to be seen if this desire for more practical work will be met.

Change
Where there is potential scope for change is with the assessment. In 2021, there was some call for a form of mini-assessment at the end of each topic to reinforce learning. There may be logistical limitations to achieve this and any change will need to be made in consultation with JMSS teachers.

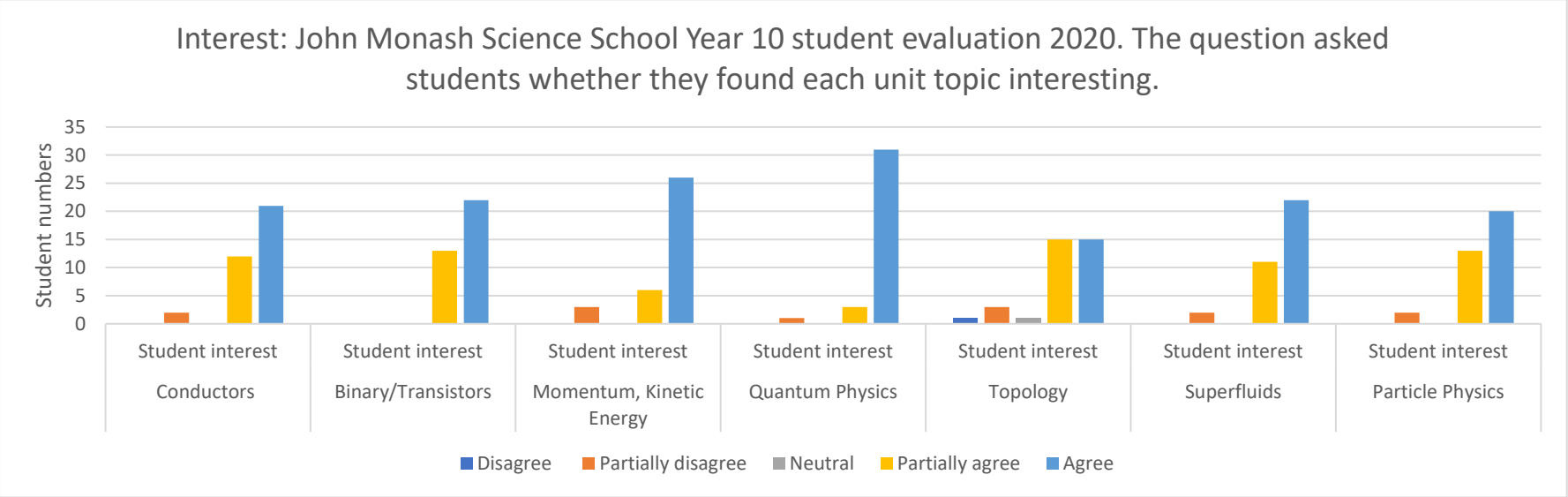
FLEET presenters are crucial
FLEET presenters played a crucial role in facilitating student enjoyment and interest in the unit. But more importantly, FLEET presenters were able to expose students to the breadth of opportunity within the physics discipline, to engage students about their research and its importance to real-world applications. FLEET presenters helped students realize the value and purpose of physics. They made physics real, palpable and inclusive. This engagement enabled students to envision multiple opportunities in physics; it opened doors and made them consider new and varied career paths. There is anecdotal support that using female presenters facilitated or enabled female students to effectively realize a place for themselves in a physics-based career. In the next 12 months, more female students will be interviewed to gain a clearer picture of what is happening here.

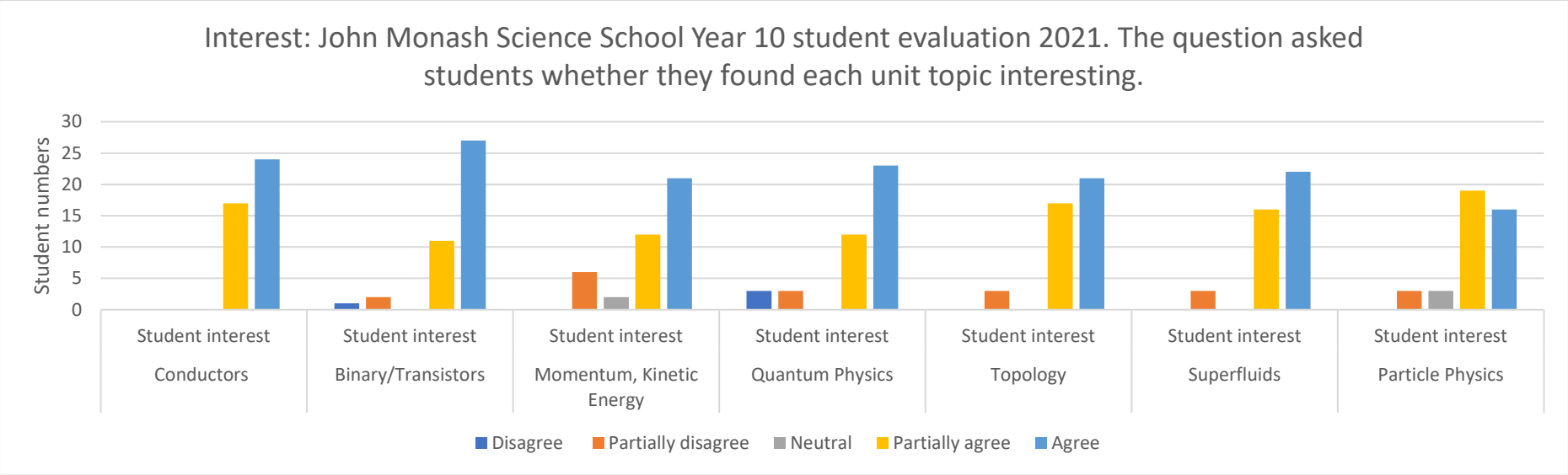
Appendix 1 Survey data for FLEET unit 2020 and 2021

Appendix 1 graphically presents the Likert-like survey data for the following questions

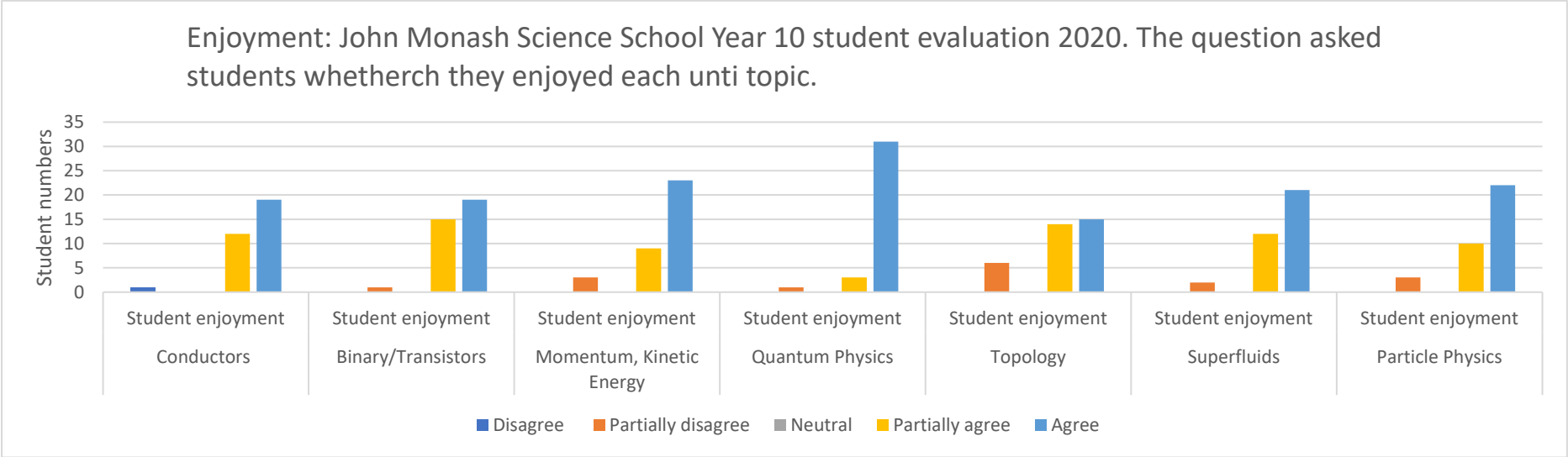
- I found this topic interesting
- I enjoyed this topic
- I found this topic difficult
- This topic was presented in a way I could understand
- I would keep this topic in the course in future years

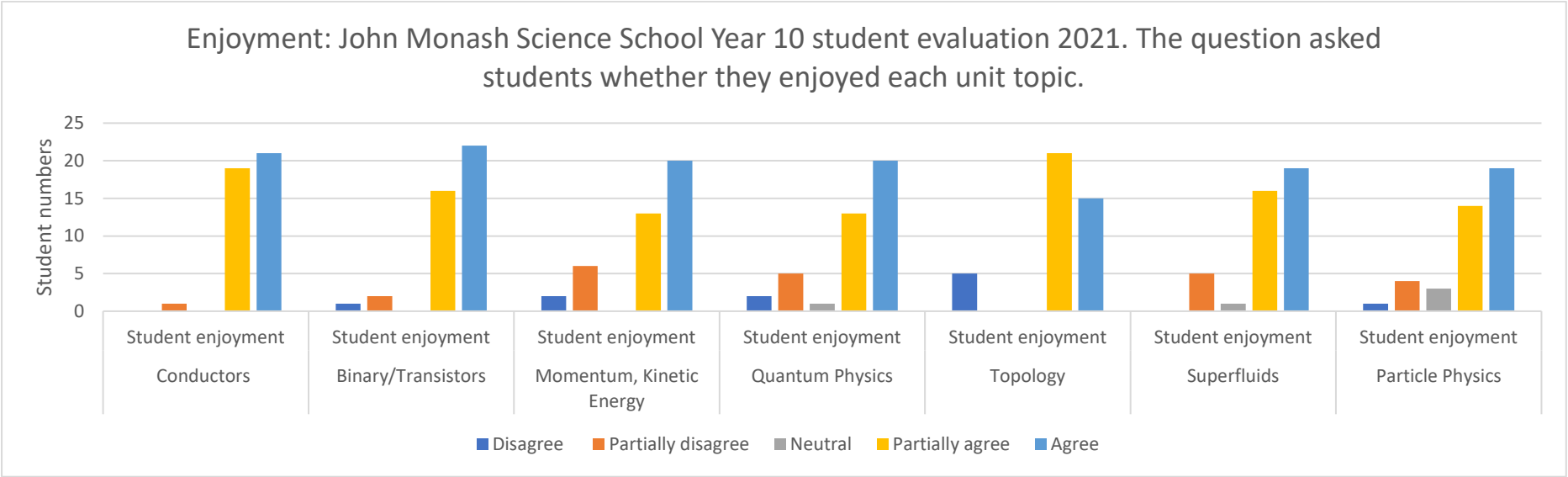
I found the topics interesting 2020 and 2021



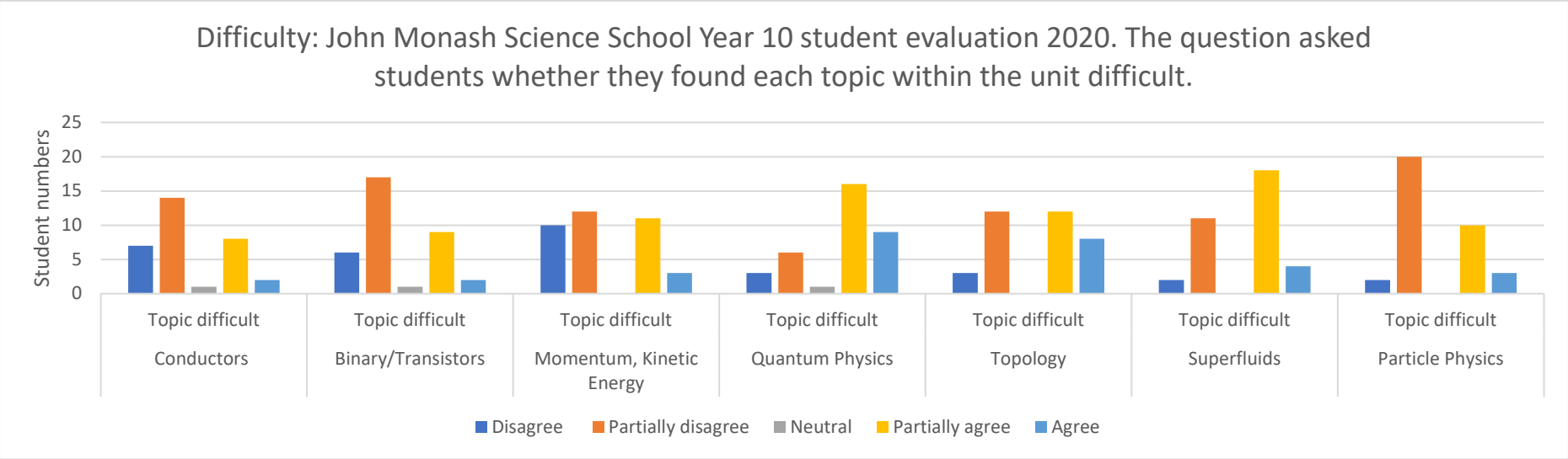

Interest: John Monash Science School Year 10 student evaluation 2021. The question asked students whether they found each unit topic interesting.
Student numbers
30
25
20
15
10
5
0
Student interest
Conductors
Student interest
Binary/Transistors
Student interest
Momentum, Kinetic Energy
Student interest
Quantum Physics
Student interest
Topology
Student interest
Superfluids
Student interest
Particle Physics
Disagree
Partially disagree
Neutral
Partially agree
Agree

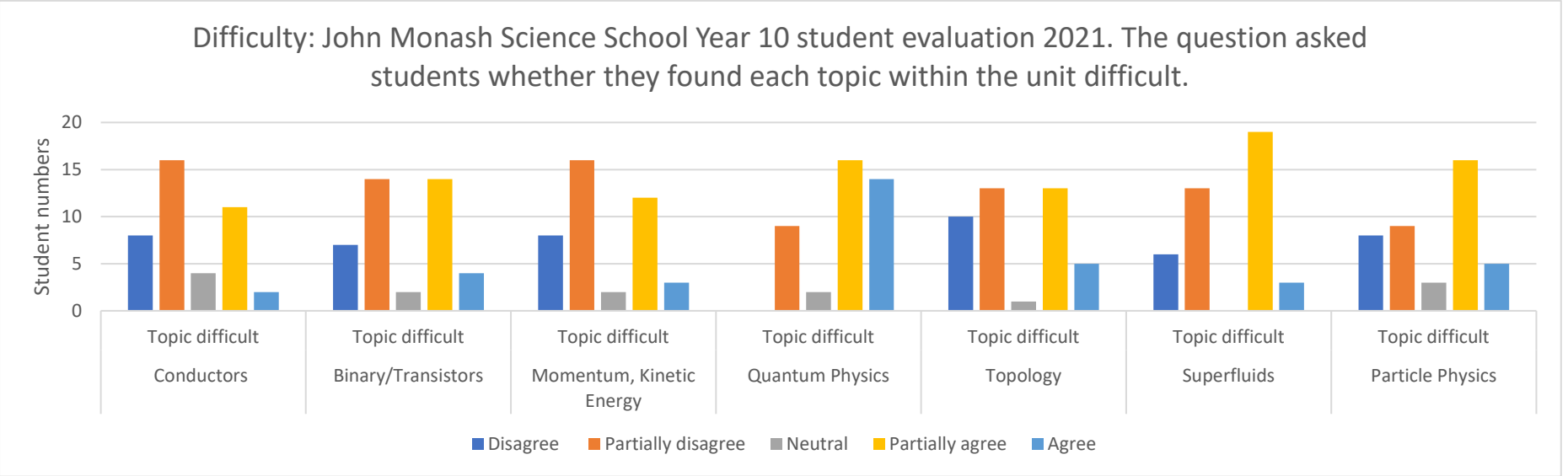
I found the topics enjoyable 2020 and 2021



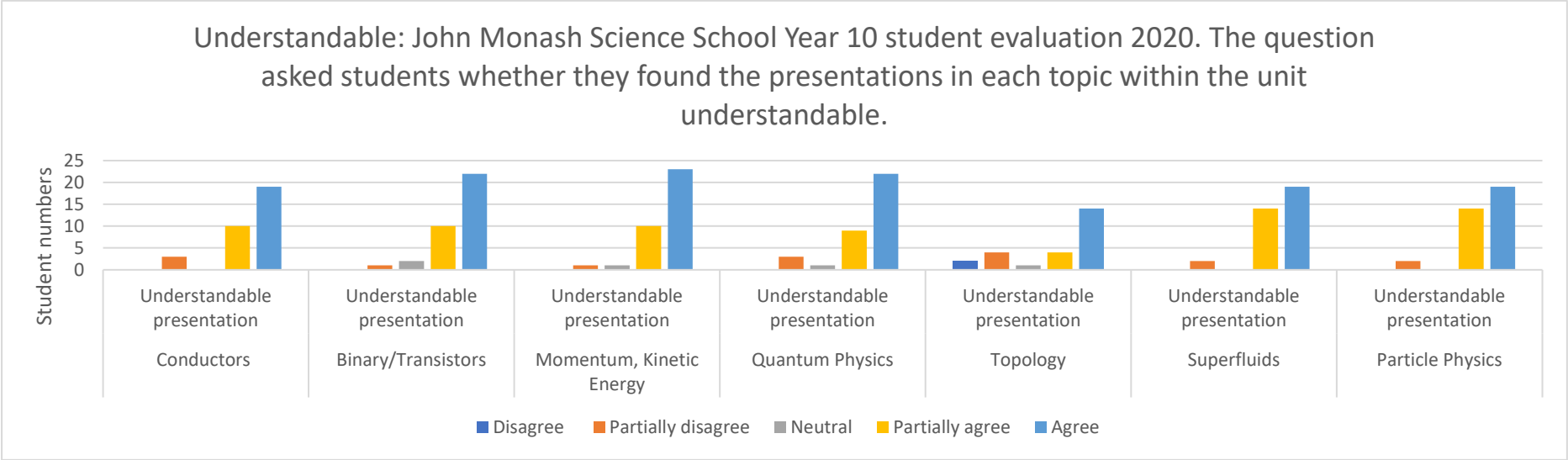


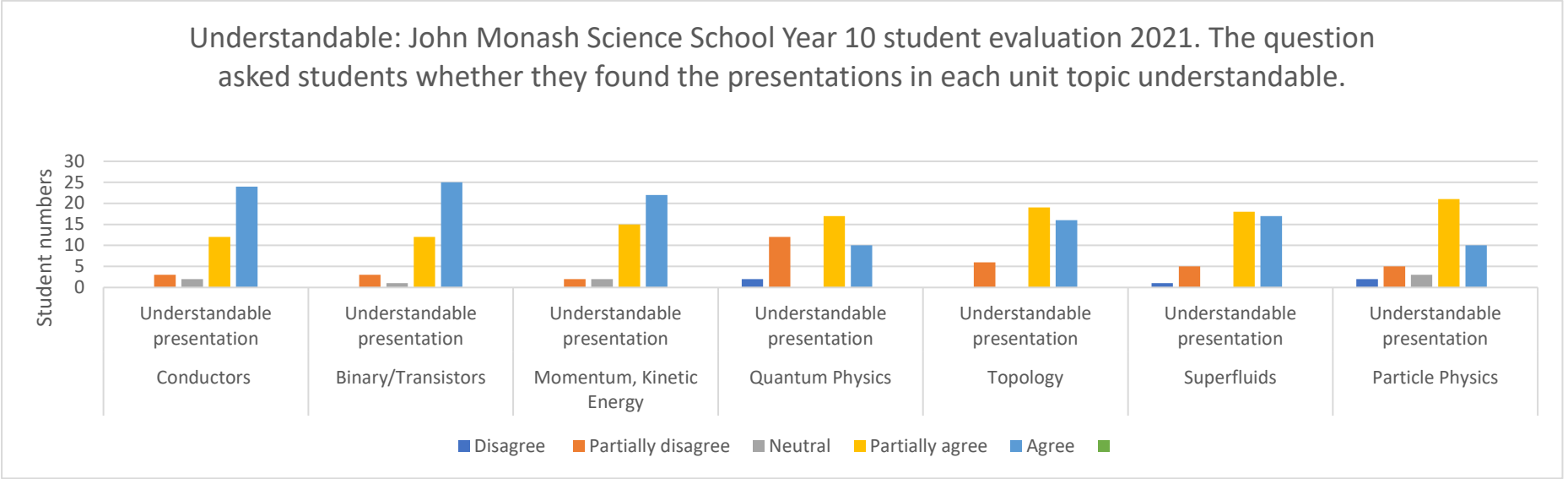
I found the topics difficult 2020 and 2021





I found the topics presented in a way that was understandable 2020 and 2021





I would keep this topic in future years 2020 and 2021