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Exploring Undergraduates' Experiences of a Two Day Quantum Summer School

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Exploring Undergraduates' Experiences of a Two-Day Quantum Summer School

Introduction

Quantum mechanics and engineering. Perhaps a combination of disciplines sounds like an output from a machine selecting STEM fields at random, but one would be mistaken to think this. Quantum mechanics is in fact foundational in engineering fields such as semiconductors, material science, and nanotechnology [1]. Quantum computing also receives quite a bit of attention, as it is seen as a definite part of the future of computer science [2]-[5]. On quantum computing in particular, MIT writes that quantum computing is no longer an interest area confined to pure science; matters of quantum computing are now crossing over into the engineering domain, which gives rise to a notion of quantum engineering [4]. All of this is not just self-advertising. In August of 2024, the NSF invested $39 million into their Expanding Capacity in Quantum Information Science and Engineering program [6]. As if the presence of quantum mechanics in engineering subjects was not enough, with quantum mechanics also being in the national science consciousness there is no doubt that it is important and that learning it will no longer be optional. All in all, quantum mechanics will only become a more necessary subject for engineers, if it is not already.

Quantum Summer School Program

Parallel to this concern of bringing quantum to engineers, is the concern that everyone who wants to be part of the quantum workforce can actually participate. The quantum information science subcommittee of the National Science and Technology Council identifies that one of the main challenges faced by Quantum Information Science and Technology (QIST) is the development of a diverse workforce [7].

This is where our project comes in. We developed and held a two-day, quantum summer school, specifically calling for underrepresented student participation, in the summer of 2024. This workshop brought in speakers from academia and industry. The academic speakers focused on presenting concepts or recent research efforts in QIST. The industry speakers gave presentations on the current interests of the industry in QIST, on starting and navigating a career in the industry, or facilitated hands on experience with the type of work done in the QIST industry.

This summer school activity was advertised through various school listservs. To participate in this summer school, there was an admission application; applications were decided upon by the project team. Each of those admitted were offered a $1000 stipend to spend on travel, food, and lodging. 27 students attended the summer school.

Research Questions

One can see that just the cost to host students was $27,000. With this being only one cost of the entire project, clearly the entire project was not cheap. Having spent this amount of money, we wanted to understand the student experience, not only to guide development of our own

future workshops but to also share with those in the QIST space concerned with outreach as well. In regard to the student experience, we were interested in understanding what made them choose our program. In particular, we would like to see higher attendance in the future, so we sought to understand what were the motivations of the students that did apply. Thus, we designed a study aimed at addressing the following two research questions:

1. What does the motivation of the attendees of the quantum summer school look like?
2. Does motivation change after attendance?

Theoretical Framework

To explore motivation, we turned to measuring it according to the concepts of intrinsic and extrinsic motivation.

Intrinsic Motivation

[8] provides a thorough definition: "Intrinsic motivation is defined as the doing of an activity for its inherent satisfactions rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards" [p. 56]. As an example of this, one can think about recreational activities. Hobbies may not produce any sort of exploitable value, but despite this, people will undertake them anyways because of some kind of joy or satisfaction they say is inherent in the doing.

[8] also explains two important conditions that foster intrinsic motivation. Intrinsic motivation comes about when there are "*feelings of competence*…accompanied by *a sense of autonomy*" [p. 58, emphasis in original]. For a more precise description of what autonomy means, [9] calls it an internal perceived locus of causality. This idea of feeling that the cause of one's activities originates from oneself is consistent with experimental methodologies that [8] reviews. Indeed, the authors say that the dominant measure of intrinsic motivation is the " 'free choice' measure" [8, p. 57]. Simply put, an individual is thought to be more intrinsically motivated the more s/he chooses to undertake an activity in the absence of any outside influences.

Extrinsic Motivation

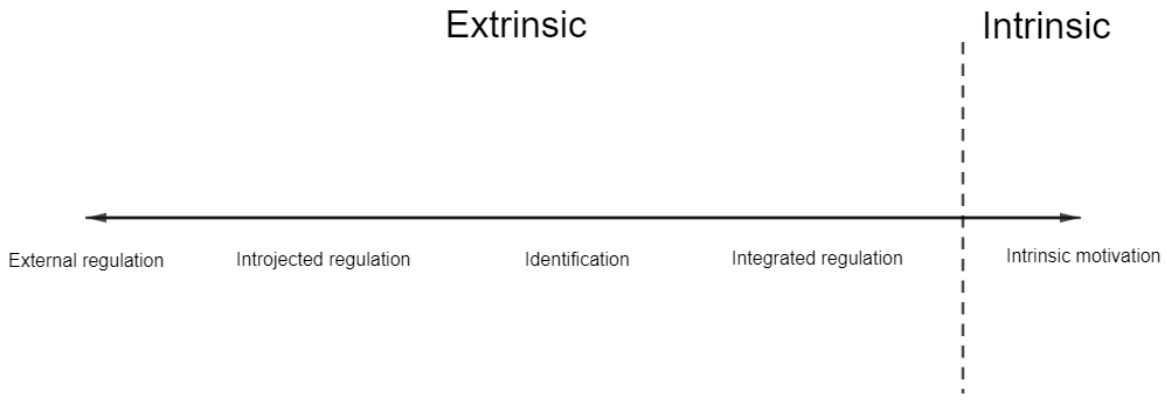
In contrast to the markers that identify when intrinsic motivation is in play "extrinsic motivation is a construct that pertains whenever an activity is done in order to attain some separable outcome" [8, p. 60]. Revisiting the idea of the perceived locus of causality, we saw that for intrinsic motivation it was internal. One can guess that for extrinsic motivation, the locus is now external. Indeed, this may be considered a "classical" view, as that is how B.F. Skinner and his peers studied the topic. An example of extrinsic motivation would be anything that involves completing something for a reward that is given from outside the self, i.e. validation or money.

While one's experience of intrinsic and extrinsic motivation may cause one to think of these two as strictly exclusive categories, there is actually more nuance to extrinsic motivation. [8] describes a continuum that starts at an external perceived locus of causality and moves towards becoming more internalized, ending with internal perceived locus of causality on the opposite end. On this continuum, motivation that is not completely internalized is still classified

as extrinsic, even though it does not look exactly like a classical display of extrinsic motivation. To delve deeper into the categories on the continuum, we have the figure below.

Figure 1

A Simple Illustration of the Motivation Continuum



On the left end point is external regulation. External regulation describes motivation that causes behaviors such that, "such behaviors are performed to satisfy an external demand or obtain an externally imposed reward contingency" [8, p. 61]. The perceived locus of causality is external [8].

Moving to the right, there is introjected regulation. This is "a type of internal regulation that is still quite controlling because people perform such actions with the feeling of pressure in order to avoid guilt or anxiety or to attain ego-enhancements or pride. Put differently, introjection represents regulation by contingent self-esteem" [8, p. 62]. The perceived locus of causality is somewhat external [8].

Moving rightwards still is identification. When acting under identification motivation "person has identified with the personal importance of a behavior and has thus accepted its regulation as his or her own" [8, p. 62]. The perceived locus of causality is now somewhat internal [8].

Nearing the right end point is integrated regulation. "Integration occurs when identified regulations have been fully assimilated to the self. This occurs through self-examination and bringing new regulations into congruence with one's other values and needs. The more one internalizes the reasons for an action and assimilates them to the self, the more one's extrinsically motivated actions become self-determined" [8, p. 62]. The perceived locus of causality is internal [8].

Finally, on the right end point is intrinsic motivation. The perceived locus of causality is internal [8].

In sum, we have distinct categories of motivation, extrinsic and intrinsic. But the existence of just two categories does not imply a strict either or dynamic. As we have seen, there is a continuum that exists between the two that has its causality more or less weighted towards one side. [8] also remarks that the continuum is not a model of development, meaning that one may start anywhere and move anywhere else. Progressing through different points on the continuum is not necessary; one may jump from one category to any other category [8].

Methods

Data collection

Following the conclusion of the summer school, students were invited, via email, to complete a survey about their summer school experience. They were given a month to complete the survey, and several reminder emails were sent in the hope of maximizing participation.

The survey, c.f. Appendix A for the survey, had 21 questions. The first three questions collected basic demographic information, c.f. Participants section. Following these demographics, students were asked what was the future career they thought they would be pursuing before and after attending the summer school. The next section of the survey asked students about their motivations for attending, before and after attending the summer school. Each question targeted one category of motivation on the motivation continuum discussed earlier. Thus, there are five questions concerning motivation before the summer school and five questions concerning motivation after the summer school. The questions were created by referencing the descriptions of motivation categories by [8] and [10] and by modeling off of survey questions from [11]. The final section of the survey asked students to rank all the summer school activities according to their most to least liked and most to least interesting, separately. For each ranking activity, students were asked to explain their most and least choices.

Participants

Of the 27 students that attended the summer school, 25 completed all the required questions on the survey. The demographic questions were optional. While most students answered all demographic questions, some did not answer the race/ethnicity question. The following figures show the breakdown of the results of the demographic questions with the total number of respondents for each question.

Figure 2

Breakdown of Respondent Gender

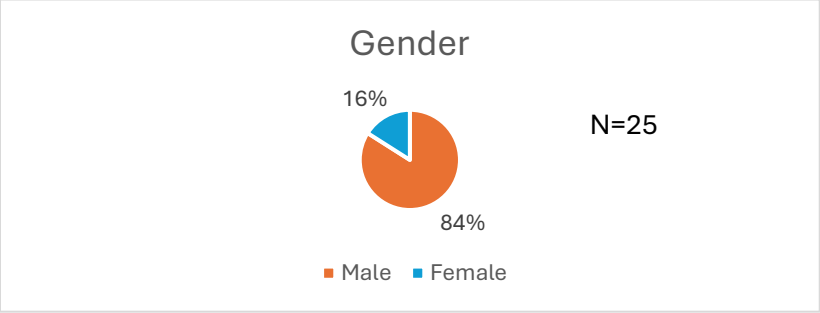


Figure 3

Breakdown of Respondent Race/Ethnicity

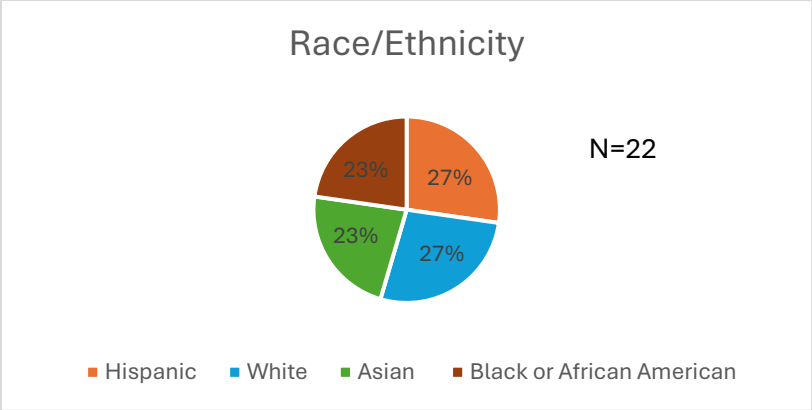
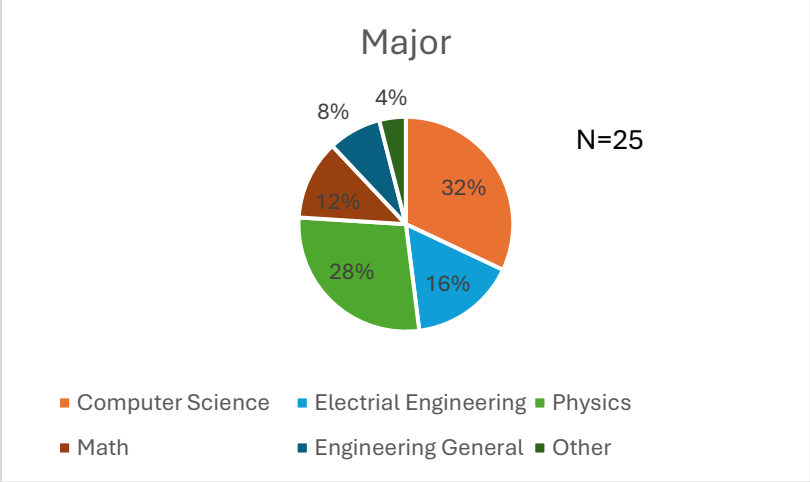


Figure 4

Breakdown of Respondent Major



Clearly, the majority of the respondents are engineering majors. Comparing our sample's gender ratio to the national average (24.6% female and 74.4% male) [12], our sample overrepresents males and underrepresents females. Unfortunately, our summer school did not attract underrepresented students in terms of gender. Comparing our sample's race/ethnicity data to the national average (5.4% Black or Afr. American, 15.8% Hispanic, 16.1% Asian American, and 53.4% White) [12], we were able to achieve greater representation in underserved student populations.

Data analysis

Due to the small sample size, we did not conduct any group means hypothesis testing. Instead, we analyzed the data by looking at the percentages of different responses of the before and after questions pairwise. For the ranking and short explanation section, we looked at the individual responses and the overall most and least liked and interesting.

Results

The following figures show the breakdown of response choices for question pairs in the multiple-choice section of the survey.

Figure 5

Breakdown of Responses to the Question Assessing External Regulation

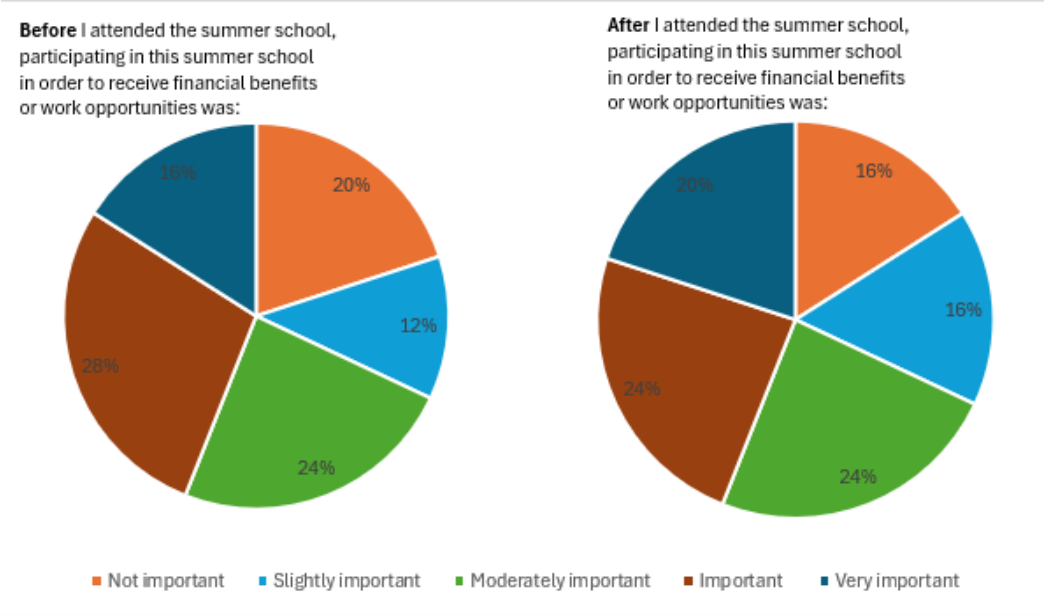


Figure 6

Breakdown of Responses to the Question Assessing Introjected regulation

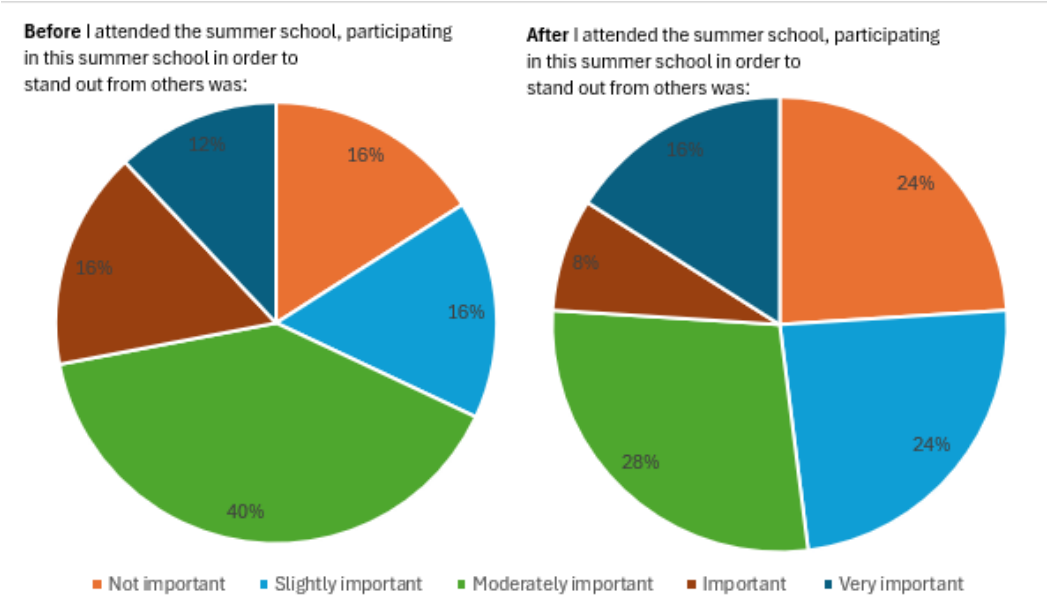


Figure 7

Breakdown of Responses to the Question Assessing Identification

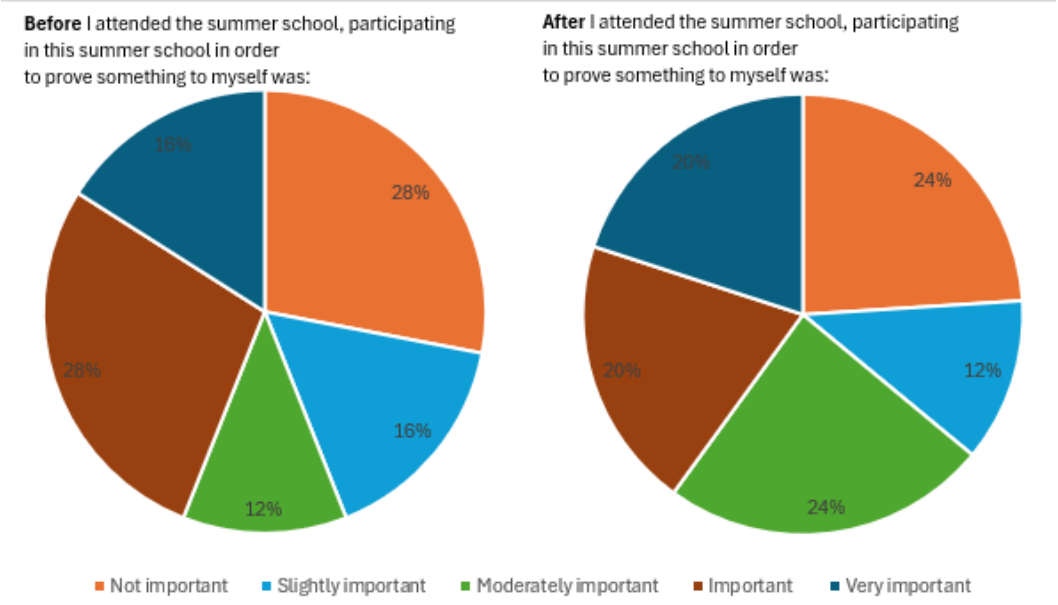


Figure 8

Breakdown of Responses to the Question Assessing Integrated Regulation

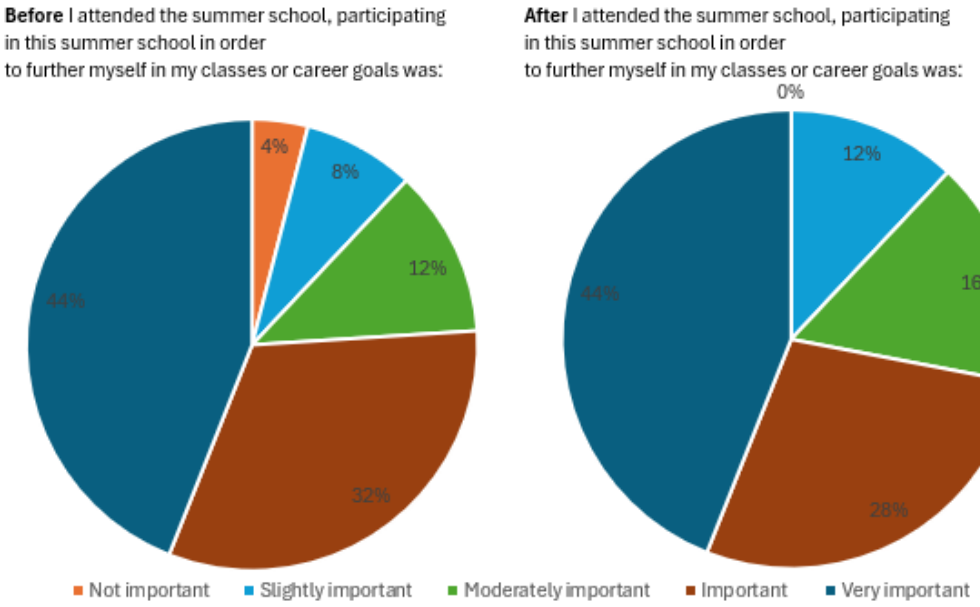
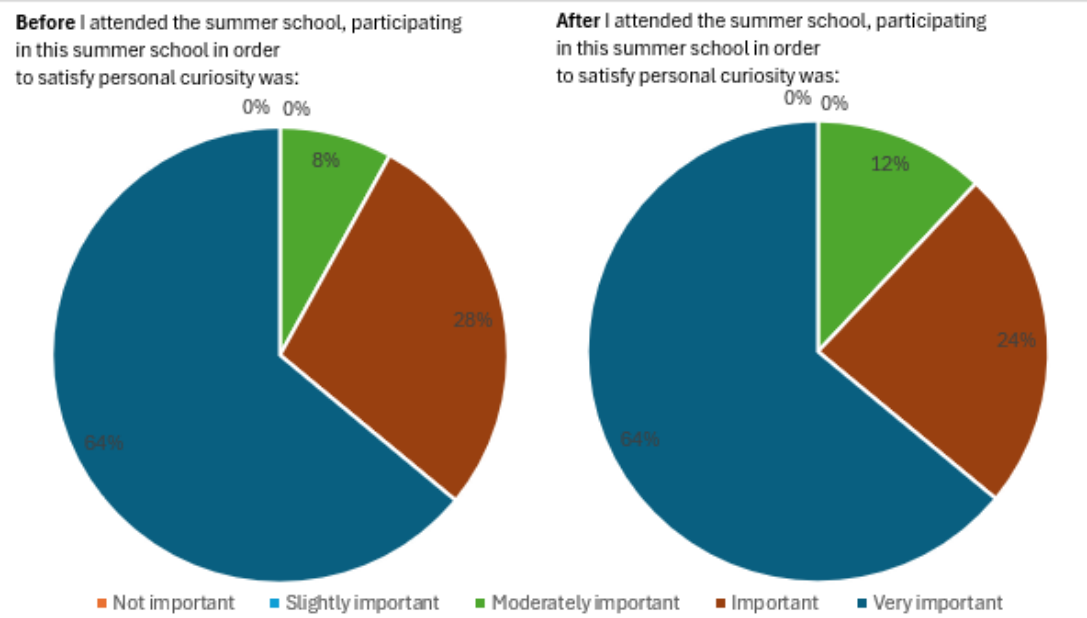


Figure 9

Breakdown of Responses to the Question Assessing Intrinsic Motivation



For the second section of the survey, it is most insightful to only highlight activities rated as the most or least liked or interesting. A talk by Professor X was the most liked (top choice for 36% of students) with a talk by Professor Y being a close second (with 32% of students making that their top choice). The least liked activity was the poster session (lowest choice for 40% of students), and an industry talk by Z was the second least liked activity (24% of students made that their lowest choice). The most interesting activity was again the talk by Professor X, though this time the choice rate was 20%. The next interesting activity is split between four different activities that each got a response rate of 12%. These activities were all talks by professors. The least interesting activity was the industry talk by Z with a response rate of 28%. The second least interesting activity was tied between the poster session and a session that let students try quantum computing for themselves (response rate was 20% for each).

The free responses explaining the most and least liked or interesting activities will be selectively covered in the discussion.

Discussion

Limitations

To preface the discussion, we will discuss limitations to this study that informed us and will hopefully inform readers on what this data ultimately means and how it can be applied to real situations. Firstly, the students are self-evaluating, which allows for bias, of which one major source could be that students responded based on how they think *we wanted* them to respond, rather than how *they actually* felt. Given that the $1000 stipend was paid out before this study began and that this study was advertised wholly separate from the summer school, we do not

suspect that students are answering according to what they think we wanted to see. Second, the students who came to this summer school self-selected into it, so we expected intrinsic motivation to be high. Third, this is not a controlled experiment, so while attending this summer school surely had some kind of effect on the students, there are no causal linkages between summer school attendance and any change in the response to the multiple-choice questions. This should not cause readers to think this study is wholly useless though. Readers should consider how similar the student demographics are to whatever situation is at hand for the reader, in order to judge if findings here may be applicable. In any case, we hope that readers can come away with useful things to keep in mind when designing and hosting a summer school or other similar program.

Research Question 1

Figures 5-9 show us that motivation is not a strict binary of either all extrinsic or all intrinsic. All types of motivation in the motivation continuum were at least moderately important to about one-third or more of the students. As noted before, intrinsic motivation and the most intrinsic adjacent form of extrinsic motivation (integrated regulation) are unsurprisingly high among the students, as an intrinsically motivated person was the most likely kind of person to be seeking and applying to an extracurricular summer activity such as this. Indeed, the free response explanations of why something was the least or most liked or interesting show that students are making this judgement from a standpoint of intrinsic motivation. In particular, something is their #1 choice because the *learning content* was personally interesting or appealing, while someone was rated the lowest because it had little to no connection to what they find interesting. The following are responses that illustrate this point:

“Content aligned with my interest the most. Presentation was clear and well-paced.”

“I really enjoyed the presentation given by [Prof. X], as I found the content quite interesting.”

“I wasn't interested and left early”

“I do not have much interest in quantum games.”

While intrinsic motivation and integrated regulation were what were driving students the most, still, financial incentive showed as a strong motivator for attending in the first place. Though, just under half the students said that financial incentive was important or very important. Given this, perhaps the stipend can be lowered without causing loss of participation. This is an important insight, since funding is not unlimited so the more students that can attend (because the individual stipend is lower) the better.

Research Question 2

From the data, we see there are mainly changes of 1-3 students changing their motivation strength for any number of the categories after attending the summer school. Of note is the change in introjected regulation (Figure 6). Students attended this workshop partly because it was moderately important to them that this would be something that would make them stand out from others, but after the workshop, standing out from others was only slightly important or not

at all. The free responses did not provide insight into why some students no longer found it important to stand out from others. Given that many talks presented field knowledge, perhaps students realized that what you know is very important in QIST.

Looking further at this, the least liked activities were the poster session and an industry talk. Students didn't comment on networking, instead they said things like:

"Compared to the other events and talks, I did not find the poster session particularly notable"

"I felt that most of the research posters were beyond my current knowledge of quantum sciences"

"wasn't very clear why there were PhD students presenting highly technical work to kids who don't understand quantum all that well-I think the intentions were good but most didn't understand"

This is interesting that an event that usually facilitates networking was the lowest rated activity because knowledge was such a barrier to accessing anything at the poster session at all. Thus, it seems that those promoting quantum workforce need to consider that *what* you know regarding QISE topics is perhaps more important than *who* you know in QIST. Further, QIST knowledge itself appears to be its own form of networking, as students showed that the poster session just did not connect with them, because they could not understand what the posters were showing.

Conclusion

This paper presented our findings on the student experience of a two-day quantum summer school we designed and held. We were able to attract greater percentages of underrepresented students vs national engineering averages. We were interested in what brought students to our summer school and if their motivations changed after having gone. We found a large fraction of the students were acting primarily out of intrinsic motivation. Extrinsic motivators, such as receiving payment, were not vitally important, so it may be possible that we can reduce our offered stipend. This will allow more students to attend, while keeping the original stipend budget. This is a useful insight for anyone designing their own all expenses paid program. Secondly, we found that QISE knowledge is perhaps its own form of networking; students indicated that what you know was more important to them than who you know. This can inform future QISE outreach efforts to focus outreach efforts on concentrated learning programs. We hope our insights will lead to scalable programs that can bring QISE to everyone.

References

[1] R. Peng, B. Dorn, A. Naeemi and N. Jafarinaimi, "Interactive visualizations for teaching quantum mechanics and semiconductor physics," *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, Madrid, Spain, 2014, pp. 1-4, doi: 10.1109/FIE.2014.7044207.

[2] L. Nita, N. Chancellor, L. M. Smith, H. Cramman, and G. Dost, "Inclusive Learning for Quantum Computing: Supporting the aims of quantum literacy using the puzzle game Quantum Odyssey," Jun. 13, 2021. https://doi.org/10.48550/arXiv.2106.07077 (accessed Jan. 13, 2025).

[3] M. L. How, "Advancing Multidisciplinary STEM Education with Mathematics for Future-Ready Quantum Algorithmic Literacy," *Mathematics*, vol. 10, no. 7, p. 1146, Apr. 2022, doi: 10.3390/math10071146.

[4] D. Ackerman, "Explained: Quantum engineering," *MIT News | Massachusetts Institute of Technology*, Dec. 10, 2020. https://news.mit.edu/2020/explained-quantum-engineering-1210 (accessed Jan. 13, 2025).

[5] V. De Maio, M. Kanatbekova, F. Zilk, N. Friis, T. Guggemos and I. Brandic, "Training Computer Scientists for the Challenges of Hybrid Quantum-Classical Computing," *2024 IEEE 24th International Symposium on Cluster, Cloud and Internet Computing (CCGrid)*, Philadelphia, PA, USA, 2024, pp. 626-635, doi: 10.1109/CCGrid59990.2024.00075.

[6] National Science Foundation, "Quantum science and engineering expands across the nation with $39M from NSF," *NSF - National Science Foundation*, Aug. 29, 2024. [Online]. Available: https://new.nsf.gov/news/quantum-science-engineering-expands-across-nation-39m-nsf

[7] Subcommittee on Quantum Information Science, "Quantum Information Science and Technology Workforce Development National Strategic Plan," Feb. 2022. Accessed: Jan. 13, 2025. [Online]. Available: https://www.quantum.gov/wp-content/uploads/2022/02/QIST-Natl-Workforce-Plan.pdf

[8] R. M. Ryan and E. L. Deci, "Intrinsic and Extrinsic Motivations: classic definitions and new directions," *Contemporary Educational Psychology*, vol. 25, no. 1, pp. 54–67, Jan. 2000, doi: 10.1006/ceps.1999.1020.

[9] R. DeCharms, *Personal causation: The Internal Affective Determinants of Behavior*. 1968.

[10] S. J. Sebire *et al.*, "'I've made this my lifestyle now': a prospective qualitative study of motivation for lifestyle change among people with newly diagnosed type two diabetes mellitus," *BMC Public Health*, vol. 18, no. 1, Jan. 2018, doi: 10.1186/s12889-018-5114-5.

[11] J. Zamarripa, I. Castillo, R. Baños, M. Delgado, and O. Álvarez, “Motivational regulations across the stages of change for exercise in the general population of Monterrey (Mexico),” *Frontiers in Psychology*, vol. 9, Dec. 2018, doi: 10.3389/fpsyg.2018.02368.

[12] American Society for Engineering Education, “Profiles of Engineering and Engineering Technology, 2023,” 2024. Accessed: Jan. 13, 2025. [Online]. Available: https://ira.asee.org/wp-content/uploads/2024/12/Engineering-Engineering-Technology-By-the-Numbers-2023-1-combined.pdf

Appendix

The Survey

For the ranking questions, the names of the people hosting the talks have been anonymized.

1. What is your gender?

[ ] Male

[ ] Female

[ ] Not listed

2. What is your ethnicity?

(Free response)

3. What is your major?

(Free response)

4. Before you attended the summer school, which of the following did you think you were most likely to pursue?

[ ] Industry job in the quantum sector

[ ] Industry job, though not necessarily in the quantum sector

[ ] Graduate study

[ ] Education sector job

[ ] Something else that is not listed here

5. After you attended the summer school, which of the following did you think you were most likely to pursue?

[ ] Industry job in the quantum sector

[ ] Industry job, though not necessarily in the quantum sector

[ ] Graduate study

[ ] Education sector job

[ ] Something else that is not listed here

6. Before I attended the summer school, participating in this summer school in order to receive financial benefits or work opportunities was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

7. Before I attended the summer school, participating in this summer school in order to stand out from others was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

8. Before I attended the summer school, participating in this summer school in order to prove something to myself was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

9. Before I attended the summer school, participating in this summer school in order to further myself in my classes or career goals was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

10. Before I attended the summer school, participating in this summer school in order to satisfy personal curiosity was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

11. After attending the summer school, participating in this summer school in order to receive financial benefits or work opportunities was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

12. After attending I attended the summer school, participating in this summer school in order to stand out from others was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

13. After attending the summer school, participating in this summer school in order to prove something to myself was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

14. After attending the summer school, participating in this summer school in order to further myself in my classes or career goals was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

15. After attending the summer school, participating in this summer school in order to satisfy personal curiosity was

[ ] Very Important

[ ] Important

[ ] Moderately Important

[ ] Slightly Important

[ ] Not Important

16. Please rank the activities and talks you experienced during this summer school from most liked to least liked. 1 is for most like. (Drag and drop in the choices order to create your ranking list.)

Opening talk by Prof. M

Talk by Prof. Y

Talk by Prof. P

Talk by Prof. V

Talk by Dr. N

Talk by Prof. F

Panel Discussion and Q&A with Speakers

Poster session

Talk by Prof. K

Talk by Prof. X

Quantum Game Club hands-on quantum programming session

Industry talk by Z

17. Please explain your most liked choice

(Free response)

18. Please explain your least liked choice

(Free response)

19. Please rank the activities and talks you experienced during this summer school from most interesting to least interesting. 1 is for most like. (Drag and drop in the choices order to create your ranking list.)

Opening talk by Prof. M

Talk by Prof. Y

Talk by Prof. P

Talk by Prof. V

Talk by Dr. N

Talk by Prof. F

Panel Discussion and Q&A with Speakers

Poster session

Talk by Prof. K

Talk by Prof. X

Quantum Game Club hands-on quantum programming session

Industry talk by Z

20. Please explain your most liked interesting

(Free response)

21. Please explain your least interesting choice

(Free response)