Examining Middle School Students' Learning Interest Following a Quantum Infused Radioactive Decay Curriculum Unit (Evaluation)

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Introduction

In a previous conference paper [1], we evaluated a Next Generation Science Standards (NGSS) aligned quantum infused, radioactive decay curriculum [2] we made. By examining learning gains and behavioral engagement, we found that students were able to learn the quantum concepts the curriculum aimed to teach, and the curriculum did not negatively impact student engagement behaviors in a statistically significant manner [1]. At the time, we had data on student learning interest, but unfortunately there were time constraints that ultimately resulted in that data not being ready for inclusion in [1]. So in this paper, we again evaluate our curriculum, this time by examining learning interest data. By adding in the findings on change in science learning interest to our findings in [1], we will be able to make more comprehensive conclusions about our curriculum.

Of course, it is not the mere adding on of data that we spent effort on sourcing but could not publish in time that brings us to this paper. Learning interest is well attested to as an important factor in learning [4], [7], [8]. As such, its examination adds a key dimension to the evaluation of the curriculum that we undertook previously. Additionally, this evaluation includes an examination across teachers of the impact of the curriculum on student science learning interest. This comparison of teachers with each other can bring further insight into the curriculum by showing if it can perform consistently, in spite of significant differences in the instructional context, such as the teacher teaching it or the classroom environment the school is able to provide.

Research Questions

Given the context from the introduction, we investigate the learning interest data through the following research questions:

1. Did student science learning interest change after the curriculum was done?
2. Are there significant differences in science learning interest change by teacher?

Instructional Context

Curriculum

Our previous paper [1] should be referred to for more detail, if such detail is desired, as what follows is only a brief overview of the curriculum. This curriculum has two main features: alignment with the NGSS [3] and seamless integration of quantum concepts into a pre-existing science lesson required by the state of Indiana. By making our curriculum align with the NGSS, specifically MS-ESS3-1 and MS-ESS1-4 [3], our curriculum satisfies Indiana's requirement for science curricula. This meant that our curriculum was allowed to be implemented right away, and it could possibly be widely implemented in the future, depending on our findings from classroom testing. The pre-existing curriculum we integrated quantum concepts into was a unit on radioactive decay, which is part of earth science. We chose this unit because we wanted to introduce students to the quantum conceptualization of randomness. Given that radioactive decay introduces students to classical randomness, we were able to structure the lesson to first teach classical randomness and then move to teaching quantum randomness. Table 1 shows the curriculum broken down by lesson with instructional time recommendation.

Table 1

The curriculum by lesson with teaching time recommendation

Lesson number and name	Instructional time recommendation
1: Intro to archeology challenge	60 minutes
2a: Radioactive decay & Isotopes	30 minutes
2b: Types of radioactive decay	30 minutes
3a: Half-life lab	60 minutes
3b: Randomness in radioactive decay	60 minutes
4a: Intro to quantum randomness	30 minutes
4b: Quantum random number generator	60 minutes
4c: Quantum-based art generation	60 minutes

There are four lessons in our curriculum, and the total instructional time needed to cover the curriculum is around 6.5 hours. The first three lessons teach students about classical randomness. The final lesson takes the knowledge learned so far and uses that to introduce and teach quantum randomness, by contrasting it to classical randomness. The fourth lesson then makes a real-world connection by having students do random number generator activities based on the live output of a real quantum computer (available at [5]). All lessons include hands-on activities, in order to promote active learning. All in all, our curriculum was designed to be an approach to teaching quantum mechanics to middle school students that offers minimal disruption to pre-existing, required curriculum and teaching timelines.

Methods

Data collection

We collected data through a science interest learning survey. We administered this survey through Qualtrics in a pre/post-curriculum manner. The time between the pre- and the post-test was either seven or eight days. The survey is an adaptation and abbreviation of the interest scales in general chemistry by [4]. There are four scales in the original survey: initial interest, maintained interest, self-efficacy, and effort beliefs. We only used the maintained interest scale, as this scale asked questions we were most interested in asking the students. We used all eight questions that were in the maintained interest scale. The question wording was changed from being chemistry specific to the generic phrase “these activities”. Our adaptation of the original survey is given in the appendix.

The questions were presented to students in two blocks of four questions each. We did this with the hope that having students answer questions in small blocks would help mitigate test fatigue. Test fatigue was a concern for a short survey like this because the students are taking this survey in addition to two other surveys within the same class period, so no single survey could be too taxing.

Participants

We collected the interest data during academic year 2023-2024. 10 in-service teachers across seven different middle schools in Tippecanoe county participated. These teachers taught either one or a couple grade levels. There were six male teachers and four female teachers; the average number of years of science teaching experience was 15. All of these teachers had taught the quantum infused curriculum in the prior academic year (2022-2023). Additionally, during summer 2022, all the teachers received professional development in form of a workshop that was an intensive three-day program covering relevant quantum mechanics topics and the quantum infused curriculum.

We collected interest data from 6th, 7th, and 8th grade students. Even though 10 teachers participated, we were only able to obtain complete data from nine teachers. This is because one teacher encountered technology issues, so one of their surveys was done on paper. We were not able to collect the paper administered surveys, which resulted in the inability to form data pairs for that teacher. Even so, we were able to collect 721 paired responses. Race, income, and gender data were not gathered from the students, due to our institutional review board not approving the collection of such demographics.

Data analysis

The interest data is Likert scaled. To score it, we assigned a number to each Likert level. This number became the score value for the response. We scored responses with a value ranging between one and five. A score of one corresponded to "Strongly Disagree", and a score of five corresponded to "Strongly Agree". One question was negatively worded, so that question was reverse scored.

To answer research question one, we first calculated the average score of the survey for each student. Then we grouped students of all grade levels into one large group. So, we had a pre- and post-curriculum group of interest survey average scores. To assess if any change had occurred, we used Welch's t-test. Given the large sample size ($n = 721$), and prior evidence of the t-test's robustness for $n > 25$ [6], we used Welch's test. By examining the mean of each group before carrying out the test, we chose the appropriate direction for a single-tailed test.

To answer research question two, we first calculated the average gain score by subtracting the average total score of the pre-curriculum condition from the average total score of the post-curriculum condition. The data was formatted to include the teacher each student belonged to. We wanted to do a one-way ANOVA in order to determine if there were any significant differences in the change of science learning interest by teacher, but first we had to check if the underlying assumptions were met. We used Levene's test to check if there was equal variance across the groups. There was not, so we used the Kruskal-Wallis test to test for differences between groups. If the result was significant, we used the paired Wilcoxon rank sum test to see which groups were statistically significantly different.

Results

Table 2 shows the result of the single-tailed *t*-test for the interest data.

Table 2

Welch's single-tailed t-test result

Science Learning Interest Survey								
df	**Pre-test**		**Post-test**		**Diff.**	***t***	***p***	**Effect Size**
	Mean	s.d.	Mean	s.d.				
720	3.76	1.11	3.75	1.17	0.02	0.668	0.25	-

Table 3 shows the result of the Kruskal-Wallis test. Table 4 shows the result of Wilcoxon rank sum test; the teacher names have been replaced by single letter pseudonyms assigned in the order of the alphabet.

Table 3

Kruskal-Wallis test result

Science Learning Interest Survey		
df	χ^2	***p***
8	25.220	0.001**

**$p < 0.01$.

Table 4

Wilcoxon rank sum test results

Teacher	*n*	Mean	s.d.	A	B	C	D	E	F	G	H	I
A	110	0.17	0.79	-								
B	67	-0.08	0.76	0.278	-							
C	104	-0.31	0.78	0.001**	0.170	-						
D	33	0.05	0.78	0.753	0.690	0.136	-					
E	48	-0.21	0.79	0.113	0.568	0.635	0.435	-				
F	84	0.07	0.55	0.690	0.460	0.003**	0.929	0.170	-			
G	106	0.00	0.57	0.155	0.960	0.072	0.635	0.524	0.278	-		
H	63	-0.04	0.65	0.402	0.836	0.114	0.794	0.482	0.635	0.836	-	
I	106	0.09	0.79	0.402	0.690	0.038*	0.894	0.317	0.585	0.794	0.836	-

*$p < 0.05$. **$p < 0.01$.

Discussion

Research Question 1: Science Learning Interest Change

The data itself shows that the mean response basically did not change from pre to post. As one might subsequently expect, the *t*-test showed there was no significant difference in the change of student science learning interest. Although an increase in interest would be desirable, maintaining interest over a short instructional window (7–8 days between administrations) can still be interpreted as a favorable outcome, given prior evidence that interest may decrease during new knowledge acquisition [7]. Combining this with our earlier findings that the curriculum supported learning gains without statistically significant negative impacts on engagement [1], it can be seen that our curriculum can teach quantum concepts with no statistically significant negative impacts to student science learning engagement or interest. This suggests that our curriculum is suitable for middle school, as it teaches its material while avoiding detrimental effects on important factors to learning like engagement and interest.

Research Question 2: Differences Across Teachers

As the results showed, there is one teacher whose gain score is statistically significantly different, compared to a handful of other teachers. The teacher pairs with a statistically significant difference are A and C, E and C, and I and C. In each statistically significant pair, Teacher C is one member of the comparison. Examining the results, we see that Teacher C's gain score compares negatively to the three other teachers. We unfortunately cannot elaborate on how or why this happened, since we do not have any classroom observation data that could help us understand why Teacher C had the worst performance.

While one teacher performed differently, in a statistically significant way, than a handful of others, we see that there are no statistically significant differences between any of the other teachers. Thus, Teacher C appears to be an outlier, relative to the remaining teachers. This leads us to conclude that the impact of student learning interest is largely independent of the teacher who taught the curriculum. This is an important result, as it means that we achieved the following design goal: our curriculum is a short, structured sequence (approximately 6.5 hours across four lessons) that can be implemented with minimal disruption to existing curricular timelines. Given this and combining it with the conclusions of research question 1, there is a worthy case for wider spread use of this curriculum.

Limitations

Several limitations constrain interpretation and point to clear next steps. First, because student demographic data (e.g., race/ethnicity, gender, socioeconomic indicators) were not collected, transferability to other contexts cannot be established. Second, we lack classroom observation data, which prevents us from explaining why Teacher C's outcomes differed. Future work should (a) incorporate qualitative classroom evidence (observations, teacher interviews, or artifacts), (b) examine longer-term trajectories of interest beyond the immediate post-test window, and (c) test whether interest effects vary by grade level or other student characteristics when permissible.

Conclusion

This paper added onto our previous work [1] by analyzing data that was not ready at the time. By investigating learning interest data, we were able to bring a final and important dimension to our evaluation of an NGSS aligned, quantum infused curriculum for middle schoolers [2]. We found that learning interest was unchanged after the curriculum, compared to its pre-curriculum level. This is a good result, since that means we did not negatively impact a factor that is important to learning. We also found that aside from an outlier, the change in learning interest was about the same across classrooms. Such is a very good result, as that means the result of no change in interest is not heavily tied to the classroom or the teacher. Certainly, future work should gather in class data to give further depth to this finding. Together with prior evidence of quantum concept learning gains and non-negative engagement effects [1], these findings support the curriculum as a promising, scalable approach for introducing foundational quantum ideas in NGSS-aligned middle school instruction, while highlighting the importance of documenting implementation conditions that may produce atypical outcomes. In looking towards a future where quantum mechanics is standard in the curriculum, our approach of integrating it into existing content, rather than making it a whole separate subject of study is a pathway that should be seriously considered.

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Appendix

The Interest Assessment Instrument

In Qualtrics, students would click the bubble corresponding to the desired response option for the question they were answering. Only one response was selectable per row. As mentioned before, the questions were organized into two blocks of four questions each.

Please read the statements below and choose the corresponding options that show what you prefer. There are no right or wrong answers to these questions.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
What we are learning in these activities is fascinating to me.	O	O	O	O	O	O
I am excited about what we are learning in these activities.	O	O	O	O	O	O
In these activities, I really enjoy the content.	O	O	O	O	O	O
To be honest, I do not find these activities to be interesting.	O	O	O	O	O	O

Please read the statements below and choose the corresponding options that show what you prefer. There are no right or wrong answers to these questions.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
What we are studying in these activities is useful for me to know.	O	O	O	O	O	O
The things we are studying in these activities are important to me.	O	O	O	O	O	O
What we are learning in these activities is important for my future goals.	O	O	O	O	O	O
What we are learning in these activities can be applied to real life.	O	O	O	O	O	O