Investigating Differences in How Teachers Facilitate the Classbook "The Radiation Around Us"

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Abstract

HEC (Hypothesis–Experiment Class) is a Japanese teaching method Kiyonobu Itakura first introduced. Similar to a gameshow, students in HEC are asked a series of problems from which to choose answers A, B, or C. After a discussion phase, the correct answer is revealed. In repeating this procedure, the students are constantly learning more about a specific topic. The first author is the first teacher to conduct the HEC lesson "The Radiation Around Us" (TRAU) at an Austrian school. Our impression is that TRAU has much potential and the first two authors are writing their MS theses on evaluating this potential. According to Itakura, HEC has three goals: growth in conceptual understanding, enjoyment of the lesson, and reproducibility of the lesson across classrooms. In this paper, we will discuss the last of those three points; namely, we look to see how increased experience does or does not affect how TRAU is carried out in the classroom. This paper accompanies the DPG Proceedings by Jeidler *et al.* which addresses the first two goals of HEC.

1. Introduction

The MS theses of the first two authors concern the curriculum “The Radiation Around Us” (TRAU). TRAU aims to teach students that radioactivity is not just something we find around nuclear weapons and power plants, but that it is all around us and always has been. TRAU aspires to have students learn this in a way that is enjoyable and that deepens student understanding also about the nature of science. TRAU has recently been translated first from Japanese into English by the third author and Prof. Haruhiko Funahashi and then from English into German by native German-speaking MS students at the University of Vienna, including the first two authors. It is available upon request to the third author.

1.1. Theoretical background behind TRAU

The original Japanese version of TRAU is an excerpt from Miyuki Yamamoto’s curriculum “Radiation and Sievert” (Yamamoto, 2011), which is an example of a Hypothesis–Experiment Class (HEC). HEC was proposed in 1963 by Dr. Kiyonobu Itakura (1930-2018) (Itakura, 2019), who specialized in pedagogy, science history, and the history of science education. HEC is intended to help improve the basic conceptual understanding of students via a cyclical process of "Problem, Expectation, Discussion, Experiment, Problem…" in the classroom (Itakura, 2019). HEC curricular materials for a given topic are comprised primarily of a Classbook, which contains readings and carefully-arranged multiple-choice questions pertaining to a series of experiments. Recently, English translations of a few Classbooks and writings by Itakura have been published (Itakura, 2019).

Since its inception, a number of HEC curricular materials have been developed to teach students a wide range of topics in both natural and social sciences, and HEC is well-known and widely used by science teachers throughout Japan. The curricular materials of HEC are comprised primarily of an indispensable “Classbook”, which students generally receive from their instructor page by page (but in our study students read instead from a projector screen to save paper). These pages contain multiple-choice questions pertaining to an experiment. Students discuss in the whole-class setting after making a personal prediction about the outcome of the experiment. Once the discussion has come to a close, the experiment is conducted or the next pages are distributed which contain the results of the experiment. The next question pertaining to the next experiment is also handed out.

In HEC, authority is given to experimental results and to the discussion between students regarding the experiments. The teacher’s role is not to be an authoritative source of knowledge, but rather to ensure that the outcomes of the experiments are clear and to facilitate discussion. For example, during the discussion, the instructor will invite students to share “any other ideas that have not been heard yet? Maybe you chose option A but you were kind of thinking B at first? What was attractive about B in the beginning?” Similarly, part of the discussion is explicitly dedicated to giving space to students who have changed their mind, such that they can share what made sense to them about the other perspective. Just as important

as what the teacher does during the discussion is what the teacher should **not** do. The teacher does not correct the errors in the reasoning of the students, but rather leaves them as they are, waiting for students to accept the scientific principle through the results of a series of carefully chosen and arranged experiments. These measures are considered crucial for the three HEC goals:

Goal 1: "Make sure each and every student gains the ability to use the central theory or concept" (Itakura, 2019, p. 20). This means that more than 90% of the students should correctly predict the correct answer to the last problem in the Classbook. In addition, it is advised to give a test on the material covered one to two weeks after completing the Classbook (Itakura, 2019, p. 20). Problems in the Classbook are carefully chosen and arranged such that this goal can be accomplished. At the same time, HEC urges teachers to refrain from testing students on things not directly discussed in the Classbook.

Goal 2: "Structure the class so that most students report that they like both science and these science classes" (Itakura, 2019, p. 21). The explicit goal is that over 50% of learners report that they "liked" or "really liked" science and the Classbook and that virtually no one reports that they "disliked" the Classbook. To ascertain this, HEC practitioners generally ask students directly whether they enjoyed their learning by having students answer a one-question survey administered immediately after the Classbook has ended (Itakura, 2019, p. 21). This question is referred to as the "*tanodo*" (translated from Japanese as "degree of enjoyment") survey. Participants choose a selection from a five-point scale, with 1 being "it was very enjoyable" and 5 being "it was very boring".

Goal 3: "Make all necessary preparations so that any teacher sufficiently passionate about education, not just special veteran teachers, will be able to teach this type of class (Itakura, 2019, p. 22)". In short, this means that HEC lessons should be easy to carry out with the help of the Classbook by any teacher, regardless of that teacher's extent of teaching experience.

In order for students to enjoy learning and to personally accept the scientific principles on the basis of demonstrated experimental results, HEC considers it essential for students to participate in the accumulation of the knowledge without having their ideas denied by the authority of the teacher; rather, student ideas are to be informed by the authority of the experimental results themselves. This is why minimal explanation, if any, is given between experiments in a Classbook. Instead, the questions are carefully arranged such that students gradually come to a scientifically-accepted understanding of the content material in a way that feels organic to them and that they are personally convinced of. Problem 6 of TRAU, for example, asks students how they would expect the gamma radiation level to change as we climb a tower to a height of 140 m (Figure 1 below). We have observed a wide range of student ideas during discussion about this question, for example, that cosmic rays increase with height, that cosmic rays are completely blocked by the atmosphere, that concrete of the tower emits radiation, and that the humidity of the air between the ground and the observation deck absorbs radiation. However, after seeing the result of the experiment (that the radiation is less at the top of the tower), students proceed immediately to Problem 7 without additional narrative. Teachers unfamiliar with HEC may be tempted to add discussion at this point about ideas students brought up that are incorrect and/or would have led to the incorrect prediction. Such additions to the original curriculum are discouraged, however, as they are seen as rejecting student ideas and "brutally forcing a theory on the student" (Itakura, 2019).

1.2. **Structure of the TRAU Classbook**

TRAU typically begins by having students construct their own cloud chambers from dry ice and rather everyday materials like Styrofoam boxes, thick paper, and alcohol. This way, when students see that tracks from ionizing radiation appear even when no radioactive source has been put inside the cloud chamber, they can recognize that it is not because of using high-tech physics equipment that is generating ionizing radiation; rather, radioactivity is part of their everyday existence. In Austria, however, it is problematic for teachers to bring dry ice into the classroom due to safety concerns. As our goal is to provide Austrian teachers with effective curricular materials that they can use relatively easily, we hence replaced the activity of having students design their own cloud chambers with having students watch videos of tracks in cloud chambers. This was justified by the study of Theyßen (2014) which found that learning gains of students studying geometric optics were unaffected whether students did hands-on experiments or used simulations. Specific to radioactivity, this result was also found in the BS thesis of Marlene Freilinger (2022) who found that student learning about ionizing radiation was not noticeably affected whether they made their own cloud chambers (using a frozen gel pack instead of dry ice) or watched and discussed videos about cloud chambers. Regarding student enjoyment (HEC goal #2), Freilinger asked students to rate on a scale of 1 ("really uninteresting") to 10 ("very exciting") how interesting they had found the lesson. She found that student interest was greatest in the class where the students succeeded in making their own cloud chambers (9.2/10). However, the gel pack design proved unreliable, and student enjoyment was lowest in the class where they failed in making tracks visible in the chamber (6.5/10) (the enjoyment of students in the video-based lessons was between these two extremes at 7.2/10). Since all of these results are

Fig. 1: Problem 6 from the Classbook TRAU. Although the experimental result is A, that the radiation at the top of the tower is weaker, it is not surprising at this point of the Classbook for students to give very sensible reasons for choosing the other two options, based upon the results of the first five Problems (Printed with permission from Miyuki Yamamoto).

above "neutral", we judged that removing the hands-on task of creating a cloud chamber would make TRAU much more acceptable to Austrian school teachers without compromising the three HEC goals.

After the introduction with the cloud chamber, students are introduced to the hand-held ionizing radiation detector (the Classbook uses a gamma detector) and Sievert unit, which is defined as a measure of the health-related effects of radiation on the human body. After this, a succession of nine "Problems" ensue that involve measuring with the gamma detector, including Problem 6 discussed above. The final problem of the Classbook that is used to assess whether the first goal of HEC is met asks "do humans emit gamma radiation?" Everything that has been discussed in the Classbook up until this point is intended to prepare students to answer this final Problem correctly. This Problem thus tests to see if students have successfully constructed the hypothesis that radiation is everywhere and constantly present.

1.3. **Motivation for our study**

The first author is the first teacher to conduct TRAU (the English version) at an Austrian school. Our impression is that TRAU has much potential and the first two authors are writing their MS theses on evaluating this potential. Although some studies were conducted during the creation and revision of Radiation and Sievert, they were primarily unpublished and anecdotal in nature. Likewise regarding TRAU, other than a MS thesis written by the TRAU developer, Mr. Takashi Goto, there are no published reports about whether the HEC goals are met or not. In this paper, we will discuss the last of the three HEC goals, that effectiveness of TRAU should not depend upon who the teacher is. Generally speaking, there is reason to suspect that a given curriculum would *not* be equally effective with all teachers. The PhD thesis of Goertzen, for example, demonstrated how graduate student teachers (TA's) did or did not faithfully implement research-based guided worksheets. These worksheets (Open Source Tutorials) emphasize the role of intuition in learning physics, aiming to have students refine their intuitions to align with the physics they are learning while coming to value the process of doing so. One of the TA's she observed, Oscar, told his students to not give much thought to the questions asking about intuition. In so doing, he severely undermined the Tutorial, making it essentially ineffective (Goertzen, 2010). We aim to investigate how prone TRAU is to teachers similarly acting in ways that compromise the effectiveness of the Classbook. In this paper, we focus on one teacher who began with no experience with HEC and who taught TRAU three times. By examining changes in how the teacher carried out TRAU, we can tell a story of how increased experience does or does not affect how TRAU is carried out in the classroom. This paper accompanies the DPG Proceedings by Jeidler *et al.* which addresses the first two goals of HEC.

2. **Methodology**

Our study involves the teaching of TRAU to 8th grade students at two different schools. The first school is a Gymnasium in Lower Austria and the second one is a

middle school in Vienna. At each school, two teachers will teach or have already taught using TRAU. Specifically, with the exception of one of the middle school teachers (the first author), all three teachers have already used TRAU with their students. This paper focuses upon one of the two Gymnasium teachers who is relatively new to the teaching profession and who taught TRAU a total of three times (the other three teachers will teach or have already taught TRAU only once, totaling six cohorts of students). Each of the three implementations of TRAU was with a different cohort of 8th grade Gymnasium students at the school of the teacher.

We focus on this teacher in this paper with the argument that novice teachers are more likely to change their teaching approaches rapidly as they "settle in" to their new profession. If we observe relatively little change in how this novice teacher facilitates TRAU across each of the three implementations, then we can suspect that more established teachers would likewise make only relatively small changes to how they teach TRAU. This would be part of meeting HEC's third goal, that the Classbooks can be used effectively even the first time by novice instructors.

The bulk of the data involved in assessing whether the third HEC goal is met comes from audio and written recordings of the six cohorts of 8th grade students learning with TRAU. Detailed descriptions of how each cohort of students progressed in coming to understand radioactivity will be compared to find similarities and differences in how the teachers implemented TRAU. The first author will draw upon data from these descriptions to build arguments that either the instruction was or was not faithful to the intentions of TRAU and the HEC approach discussed above, and these arguments will be discussed with the third author. Together, data from other segments of the audio transcripts will be drawn upon to reinforce or refute these claims and the arguments will be refined in a manner consistent with the constant comparative method (Kolb, 2012).

In addition to these in-class recordings, the first author has also interviewed each of the other three teachers in one-on-one interviews after their teaching with TRAU to see if the teachers felt satisfied with TRAU and to discover what, if any, problems they had faced. The interview protocols consisted of the following prompts:

- How difficult was the lesson to prepare and how long did it take?
- What was the biggest problem that occurred during the lesson?
- How does the style of instruction compare with what you usually do?
- Is there anything you found strange about the Classbook approach?
- Were there any times that you deviated from the Classbook? If so, how and why?
- Do you feel like your students were actively involved in their learning with the Classbook? More than usual? Less than usual?
- Do you feel like the discussion in the class was dominated by just a few students, or do you feel that everyone was contributing?
- Will you use the Classbook in future lessons?

These interviews serve as secondary sources of data to triangulate the accounts of teachers with the perceptions of the first and third authors regarding what happens in the TRAU classrooms. As such, they serve as secondary sources of data and were kept relatively short (10 – 15 minutes). Due to COVID-19, Zoom was used to conduct and record all three interviews.

3. **Results**

Generally speaking, only two changes were observed across the three times that the novice instructor facilitated TRAU, and they were both rather minor. The first difference was the degree to which the teacher had students read the Classbook out loud. In the first implementation, the teacher did most of the reading for the students. In the third implementation, the teacher asked the students to do most of the reading, and intentionally called on the students who were silent during the discussion phase to read the next part. The teacher reported, in the interview, an increased confidence in the third implementation compared to the first. We find it plausible that this increase in confidence may have resulted in an increased willingness to give control to students in reading the Classbook. Particularly in the first implementation, the teacher reported, it felt strange to read so much, as reflected in the following quote.

Ja, also es war für mich und die Schüler ungewohnt, dass wir so viel gelesen haben. Also das ist in meinem Unterricht eigentlich nicht so. Es wird zwar viel geredet und diskutiert, aber dass man so richtig lesen ist eher selten der Fall, bis auf Artikel oder solche Dinge ab und zu, aber aus Büchern eher nicht. Das war am Anfang etwas ungewohnt und habe mir gedacht, dass es schon lange dauert, bis man zur ersten Aufgabe kommt.

The second difference we observed was that the teacher took more time to explain the Classbook structure and HEC learning format in later implementations. In the interview, the teacher described greater familiarity with the Classbook as time went on, as reflected in the following quote.

Ich habe gemerkt, dass ich bei der dritten Klasse auf jeden Fall am sichersten war. Da habe ich schon gewusst wie es abläuft und ich habe gemerkt, dass es gut war, dass ich es öfter gemacht habe und nicht nur ein Mal.

We find it plausible that the extra time spent explaining the HEC format to students resulted from this increased familiarity with the Classbook itself and with

what students in earlier implementations had found unusual.

These two differences are sufficiently small that we do not think they would lead to a significantly greater likelihood of obtaining the first two HEC goals (about conceptual learning gains and student interest). We see this intra-teacher consistency as being some evidence that the third HEC goal is met in TRAU: extent of teaching experience does not play a major role in how teachers facilitate TRAU. As early as the first implementation, the novice teacher was following the HEC procedure described above.

Additional evidence that the third goal of HEC is satisfied with TRAU comes from the teacher's response to the first question about how difficult it was to prepare for facilitating TRAU. The teacher said that, although some questions did arise while preparing, the questions were readily answered by the second author (who teaches at the same school), and not much time was needed to prepare:

Genau also ich habe mir das damals in den Semesterferien mal angeschaut und alles durchgelesen und ein paar Fragen mir notiert, wie das mit dem Abfragen genau gemeint ist und dem Notieren an der Tafel. Da habe ich dann den Maximilian Jeidler ein paar Dinge gefragt, wo mir Sachen unklar waren. Ansonsten ist die Vorbereitung eigentlich schneller als gedacht gegangen, weil alles eigentlich im Guide super erklärt ist. Eben wie gesagt ein paar Sachen habe ich nicht ganz verstanden wie sie gemeint sind. Aber ansonsten hat das dann eigentlich relativ schnell funktioniert.

The answers to these questions can readily be added to future versions of the German translation of the HEC instructor's guide. Since preparing for TRAU (especially when no cloud chambers are actually assembled) requires relatively little time, we see that even busy and preoccupied teachers can succeed in teaching it, giving further evidence that the third goal of HEC is being met.

4. Outlook

In this paper, we have presented an abbreviated case study of one teacher who facilitated TRAU. The teacher was a novice instructor in general and was completely new to HEC and TRAU. The teacher said that, at first, it felt strange to read so much out loud from the text during class. After three implementations of the Classbook, the teacher reported increased understanding of the process and accompanying confidence, and we observed an increase in how much the teacher had students read the Classbook out loud during class and in how much the teacher explained about the Classbook and the HEC process. Although these are changes, our point is that these changes are relatively small. Since this was a novice teacher, we can expect that experienced teachers would exhibit even smaller changes in how they facilitate TRAU from implementation to implementation. We see this stability as evidence that even inexperienced teachers can successfully facilitate TRAU, which is the third goal HEC places on each of its Classbooks. Indeed, the novice teacher discussed above was able to make sense of the HEC approach sufficiently well to stay true to the teacher's guide even in the first implementation.

In future work, transcripts from the class of all four teachers will be created and compared with each other and with the teacher's guide to see the extent to which the teachers stayed true to the HEC approach, and if and how these differences influenced interest and learning of students.

It remains a question for future research how teachers in Austrian schools will respond to TRAU and to HEC in general. Even if all three goals of HEC are satisfied, if teachers do not enjoy teaching in the HEC manner, then it is unlikely to be disseminated. The first author has found teaching with TRAU to be enjoyable for himself and his students, as it feels like playing in a quiz show. The novice teacher, when asked in the interview "will you use the Classbook in future lessons?" responded very favorably with "absolutely yes":

Absolut ja. Ich war am Anfang ein wenig gespannt wie das wird, wie die Schüler das aufnehmen und wie ich das finde. […] Aber es ist wirklich so ein cooles Thema. Es wird von den Kindern so gut aufgenommen und man kann so viel drüber reden und diskutieren. Vor allem weil es eben so allgegenwärtig ist das Thema. Und da muss ich wirklich sagen, es ist es ein super Einstieg in das Thema. Ich hätte es sicher nicht so interessant gemacht, dass gleich mal alle Kinder wissen, ok Radioaktivität umgibt uns. Also das finde ich auch das Schwere, dass man es ihnen beibringt. Genau durch dieses Unterrichtkonzept wird das so gut übermittelt und ich glaube wirklich, dass ich das beibehalten werde.

Here, the teacher is expressing passion not only about the topic of radioactivity, but about the Classbook's approach to teaching it in particular, saying that TRAU does a great job of conveying that we are surrounded by ionizing radiation. The teacher voiced intention to use the Classbook again in the future. Whether the teacher (and other teachers) actually do so or not is a question warranting future research.

5. Literature

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