Teaching for sustainable development in vocational education

Annika Forsler, Pernilla Nilsson & Susanne Walan

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ABSTRACT

The pursuit of sustainable development is a necessity for life on Earth and the future of humanity. Education is important in this endeavour; therefore, creating knowledge about teachers’ teaching for sustainable development is essential. This study aimed to investigate how Swedish upper secondary science teachers adjust their teaching of the environmental dimension in sustainable development to the different vocational education programmes their students attend. Data were collected through individual semi-structured interviews with 15 in-service science teachers and analysed by thematic coding. The result showed that most teachers (but not all) adjusted their teaching to the students’ vocational educational programme; however, they did it to different extents and in different ways. The result presents teachers’ descriptions of and arguments for adjusting their teaching linked to the pedagogical content knowledge (PCK) framework. The PCK framework is used as a theoretical lens in this study. Further research is needed to investigate how science teachers’ adjustments to students’ vocational education affect the students’ knowledge of the environmental dimension in sustainable development and how that affects actions in their future professional life.

ARTICLE HISTORY

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KEYWORDS

Learning context; environmental education; pedagogical content knowledge; sustainable development; vocational education

Introduction

Climate change and rapid loss of biodiversity are among the urgent environmental issues for which humanity bears responsibility and which must be addressed by humans. Humanity is the most significant force for making changes that ensure a sustainable future for life on Earth (e.g. Folke et al. 2021). The concept of sustainable development implies a development that satisfies today’s needs without compromising the ability of future generations to meet their needs. Humanity’s challenges involve the interaction between environmental, social, and economic dimensions of sustainable development (World Commission on Environment and Development 1987). This study focuses on the environmental dimension, although all three dimensions are interlinked to a great extent.

Education is likely an important factor in achieving sustainability, as it has an excellent opportunity to influence the knowledge and abilities of society’s future adult citizens (Boeve-de Pauw et al. 2015; Timm and Barth 2021; UNESCO 2012). In the near future, students currently attending vocational education at upper secondary school will enter working life. In different ways, in their different careers, they will then have the opportunity to make choices that mitigate environmental problems and benefit sustainable development. Consequently, upper secondary school is very important as the last level of education before working life for many students, and students need knowledge to make informed decisions on questions concerning sustainability.
Teachers play a crucial role in the success of students’ learning, and there is a strong connection between teachers’ capacity to create meaningful learning environments and student learning outcomes (Darling-Hammond 2000; Hattie 2008). Pedagogical content knowledge (PCK) is a cornerstone of teachers’ professional knowledge and expertise (Loughran, Berry, and Mulhall 2012), and PCK is the knowledge that teachers develop through experience over time (Gess-Newsome 2015). Several studies within science education have reported that teachers’ PCK affects students’ learning (e.g. Alonzo and Kim 2016; Gess-Newsome et al. 2019; Keller, Neumann, and Fischer 2017; Kunter et al. 2013; Rollnick et al. 2008).

This study examined science teachers’ PCK of the environmental dimension in sustainable development in their teaching on vocational education programmes. The Swedish school system has different vocational education programmes at upper secondary schools, such as building and construction or vehicle and transport vocational education. In the study, 15 in-service upper secondary science teachers were interviewed to capture their PCK for teaching sustainable development. To our knowledge, no previous research has examined science teachers’ PCK in sustainable development, focusing on the learning context of vocational education. Therefore, there is a knowledge gap to be filled. The research question guiding this study was: In what ways do science teachers adjust their teaching of the environmental dimension in sustainable development to different vocational education programmes? As such, the results of the study might add to the knowledge base for teaching sustainable development to different students in particular learning contexts, to promote students’ engagement and learning in sustainable development. Except for the contribution to the research community, the study is expected to contribute valuable insights for curriculum developers and inspire science teachers to reflect on teaching for sustainable development in vocational education.

**Background**

**Theoretical framework**

Almost 40 years ago, Shulman (1986, 1987) introduced the concept of PCK and claimed that teachers’ content and pedagogical knowledge could be compared with an amalgam that forms teachers’ unique professional understanding. Further, Shulman highlighted the importance of teachers’ contextual knowledge in promoting students’ engagement and learning. Since Shulman introduced the concept of PCK, it has been adopted and adapted in research internationally. Many researchers (e.g. Gess-Newsome 2015; Magnusson, Krajcik, and Borko 1999; Park and Chen 2012; Park and Oliver 2008) have explored how PCK develops and how this development might be successfully supported. In 2015, a definition of PCK was formulated:

Personal PCK is the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes. (Gess-Newsome 2015, 36)

Further development of the PCK concept came in 2016 when an international group of leading PCK researchers gathered to discuss and learn from each other (the 2nd PCK summit). Out of these discussions, the researchers became unified in their understanding of PCK in science education, and an improved model of PCK was developed – the Refined Consensus Model (RCM); see Figure 1 (Hume, Cooper, and Borowski 2019). The RCM has three distinct realms of PCK: collective PCK, personal PCK, and enacted PCK. The collective PCK means PCK knowledge held collectively, such as the collected research, taking a broad perspective, or local teacher teams in a narrower sense. A teacher’s personal PCK is the cumulative PCK of an individual teacher that contains the reflection of the teacher’s teaching and learning experiences (Carlson et al. 2019). Teachers utilise enacted PCK when planning, carrying out the teaching, and reflecting on it (Carlson et al. 2019). In addition, knowledge exchange occurs between the realms of PCK. The RCM is held together by
an outermost circle representing different aspects of a teacher’s broader professional knowledge base. Those aspects are content knowledge, pedagogical knowledge, knowledge of students, assessment knowledge, and curricular knowledge (Carlson et al. 2019).

In RCM, a concentric circle separates collective PCK and personal PCK, called the learning context. The learning context depends on a multitude of factors that can be gathered in three groups: the broader educational climate (e.g., national standards and requirements), the specific learning environment (e.g., school and classroom), and individual student attributes (e.g., age, grade level, dispositions, prior experiences, and cultural beliefs). The learning context in RCM symbolically situates science teaching and learning in space and time and functions as both an amplifier and a filter for teachers’ knowledge and skills, mediating teachers’ actions (Carlson et al. 2019).

Chan and Hume (2019) systematically reviewed the science education literature to identify how researchers investigated science teachers’ PCK from 2008 onward. Their review showed that researchers conceptualise and work with PCK in many different ways, forming six knowledge categories of PCK; see Table 1 (Chan and Hume 2019).

The different knowledge categories of PCK that Chan and Hume presented in their review are all important; they are interdependent and influence each other in a teacher’s performance of teaching. However, the knowledge categories that stand in the foreground in this article are contextual knowledge, curricular knowledge, and knowledge of students. This article equates learning context in RCM with the knowledge categories (Chan and Hume 2019) of context, curriculum, and students in combination.

Although this study focuses on the theoretical framework of PCK, it is also connected to research in sustainability education, as sustainability is the teaching content examined in the study. This study relates to other research fields, such as Education for Sustainable Development (ESD). ESD acknowledges the complexity of teaching sustainability, while also raising democracy issues.
Table 1. The different knowledge categories of PCK (Chan and Hume 2019, 15–17). In this article, contextual knowledge, curricular knowledge, and knowledge of students are in focus. They are therefore marked in italics.

<table>
<thead>
<tr>
<th>Knowledge category</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment knowledge</td>
<td>Assessment knowledge encompasses teachers’ knowledge of formative and summative assessments, both the knowledge of design assessments and action-taking based on assessment data.</td>
</tr>
<tr>
<td>Content knowledge</td>
<td>Content knowledge implies the part of teachers’ subject matter knowledge pertinent to the teaching task.</td>
</tr>
<tr>
<td>Contextual knowledge</td>
<td>Contextual knowledge concerns teaching contexts and includes teachers’ knowledge of the school setting in which they work.</td>
</tr>
<tr>
<td>Curricular knowledge</td>
<td>Curricular knowledge is about teachers’ knowledge of the curriculum, its goals, structures, scope, and sequence.</td>
</tr>
<tr>
<td>Knowledge of students</td>
<td>Knowledge of students concerns teachers’ knowledge of students’ cognitive development and variations in their approaches to learning.</td>
</tr>
<tr>
<td>Pedagogical knowledge</td>
<td>Pedagogical knowledge refers to teachers’ general teaching skills, such as knowledge and skills in learning theories and classroom management.</td>
</tr>
</tbody>
</table>

(Öhman and Östman 2019; Sund 2015). In ESD, the teachers’ teaching practices include interdisciplinary teaching, participation in real-life issues, and action competence. Action competence indicates that teachers create opportunities for students to identify and take an active position on issues within the environmental area (Olsson, Gericke, and Boeve-de Pauw 2022; Sass et al. 2023). This article investigates teachers’ adjustments to their students’ vocational education when teaching for sustainable development. As such, this study will contribute to ESD, as it gives one perspective on the complexity of teaching for sustainable development: the adjustment to vocational education.

**Research with a focus on learning context**

As described above, this study focused on science teachers’ teaching about the environmental dimension of sustainable development in different vocational education programmes. The situation whereby science teaching can be adjusted to vocational education is symbolised and explained in this article with the learning context in RCM. Few researchers have explicitly focused on the learning context of PCK in RCM. However, research has been conducted within the three knowledge categories of PCK that this article assumes are included in the learning context: context, curriculum, and students. Below, findings from four previous research articles and one thesis focusing on these knowledge categories of PCK are presented. As described previously, the learning context in RCM depends on a multitude of factors gathered in the groups: the broader educational climate, the specific learning environment, and individual student attributes (Carlson et al. 2019).

Qhobela and Kolitsoe Moru (2014) investigated the impact of the learning context on science teachers teaching in Lesotho because of wide-ranging resource challenges. They investigated the learning context in terms of the broader educational climate. Further, Liu and Xu (2018) focused on the varying learning context between two geographically different districts in China (Handan and Beijing). They analysed practical teaching demonstrations by three pairs of biology teachers, each comprising one teacher from Beijing and one from Handan. The result showed differences between the teachers’ enacted PCK, depending on the different learning contexts in which they worked. Accordingly, they investigated the specific learning environment in the learning context. Another learning context that has been investigated is how teachers’ PCK was developed by carrying out teaching in line with a citizen science project. The project involved observing wild bees and identifying butterflies. The teachers’ PCK development was captured using the PCK reflection tool, Content Representation (Loughran, Mulhall, and Berry 2004). The aim was to create knowledge about how best to link citizen science projects to the school curriculum (Scheuch et al. 2018). Thus, they highlighted the first and second groups of factors for the learning context. In Bunyamin’s
(2017) thesis, the characterisation of science teachers’ enacted PCK in a developing country with a highly centralised education system was examined. The result showed that two national contextual amplifiers, the national assessment and curriculum, were strongly associated with the teachers’ ePCK. Consequently, the focus of the thesis was on the first group of factors. Finally, Tay and Yeo (2018) focused on the third group of factors for the learning context: individual student attributes. In a learning context of model-based teaching, they examined an upper secondary science teacher who enacted micro-actions and how those actions supported the specific students’ learning. The analysis identified eight pedagogical micro-actions: clarification, evaluation, explanation, modification, exploration, referencing conventions, focusing, and meta-representing. Tay and Yeo (2018) concluded that these micro-actions supported the students’ learning related to the conceptual, cognitive, discursive, and epistemological aspects of modelling.

**Sustainable development in the Swedish curriculum**

For upper secondary education in Sweden, there is an overall provision written into the curriculum concerning sustainable development in teaching:

The environmental perspective in teaching should give the students insights so they can contribute to preventing harmful environmental impacts and acquire a personal approach to the overall and global environmental issues. The teaching should highlight how society functions and how our way of life and work can be adapted to create sustainable development. (Swedish National Agency for Education 2023a)

Further, the curriculum includes learning objectives for the different vocational education programmes that all teachers must strive to reach (Swedish National Agency for Education 2023c). Sustainable development is expressed differently depending on the vocational education programme concerned. Some examples of how this is expressed in the curriculum are shown in Table 2.

All students who attend vocational education follow a compulsory science course in their three years of education. Also for this course, particular content in the curriculum is identified as content

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**Table 2. The curriculum’s vocational education learning objectives for sustainable development (Swedish National Agency for Education 2023c).**

<table>
<thead>
<tr>
<th>Vocational education</th>
<th>Requirements in the curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC and Property Maintenance</td>
<td>The education should increase the students’ environmental awareness and develop their ability to transform knowledge about the environment, ecology, and resource use into practical action. Students must be given opportunities to understand how efficient energy use leads to sustainable development. In the case of new construction, conversion of the existing building stock, repair, maintenance, and installation, knowledge is required of which systems and products are the most efficient and how to work with the greatest possible environmental consideration.</td>
</tr>
<tr>
<td>Sales and Service</td>
<td>Within the professional field, students must be able to discuss and reflect on environmental aspects and the company’s role in society.</td>
</tr>
<tr>
<td>Handicraft</td>
<td>The education should lead to students understanding the role of the artisan in society and gaining insight into the consequences of handling and choosing materials for people and the environment.</td>
</tr>
<tr>
<td>Vehicle and Transport</td>
<td>The students must develop knowledge of, and skills in, choosing the right equipment and method for performing tasks regarding the environment, quality, safety, and economics. The students must also develop the ability to carry out various tasks based on requirements for sustainable development.</td>
</tr>
<tr>
<td>Electricity and Energy</td>
<td>The education should provide knowledge about business conditions, finances, and direct and indirect environmental impact.</td>
</tr>
<tr>
<td>Building and Construction</td>
<td>Since work with building and construction affects society’s infrastructure and the environments in which one lives, education must provide knowledge of rational, safe, and environmentally sustainable construction. The students must be able to choose, use and care for materials, tools, and machines concerning safety and the environment, quality, and economics regarding production and life cycle costs.</td>
</tr>
</tbody>
</table>
that all science teachers should teach. The syllabus describes the subject of science: ‘The subject is interdisciplinary with a foundation in biology, physics, geoscience, and chemistry’ (Swedish National Agency for Education 2023b). Concerning the course’s main content of sustainable development, the requirements concern:

Questions about sustainable development: energy, climate and ecosystem impact. Ecosystem services, resource utilisation, and the carrying capacity of ecosystems. (Swedish National Agency for Education 2023b)

Different aspects of sustainable development, for example, in terms of consumption, resource distribution, human rights, and gender equality. (Swedish National Agency for Education 2023b)

Method

The context of this study

In Sweden, compulsory school ends when students are 15–16 years old. Then follows upper secondary education when students are 16–19 years old. This stage is voluntary, but most students attend. Upper secondary school is divided into different study paths, of which twelve are vocational education and six are for education towards higher education. The twelve vocational education programmes contain one compulsory science course. In the Swedish school system, the science course accounts for two per cent of the total three-year upper secondary education. It is the only science education that students in vocational education take.

Participants

Fifteen in-service science teachers participated in the study: eight women and seven men. The teachers worked at five different upper secondary schools in five different municipalities in mid-Sweden. All the participants were science teachers and had experience of teaching students attending vocational education in upper secondary school. The teachers were selected randomly, and participation was voluntary.

Data collection and ethics

In this qualitative study, individual semi-structured interviews were performed with the teachers, and all the interviews were audio recorded. The data consists of selected parts from the interviews that lasted approximately 60 minutes each. The handling of this data followed the ethical guidelines for scientific research recommended by the Swedish Research Council (2017). Informed consent was obtained from all the subjects involved in the study. In the results section presented in this article, the teachers have been given pseudonyms to keep their identities anonymous.

Data analysis

All interviews were in the teachers’ mother tongue, Swedish, and were transcribed verbatim. A thematic analysis was performed in line with the description of Braun and Clarke (2006). In the first phase of the analysis, the first author read and re-read the data, noted initial ideas, and chose data relevant to the research question. In the second phase, the first author coded preliminary interesting features of the data systematically across the data-set chosen for this article and collated data relevant to each code. Before entering the third phase of the analysis, the first two steps were discussed with the second and third authors. In the third phase, the first author collated codes into potential themes and gathered all data relevant to each potential theme. Thereafter, in the final step, all the authors jointly discussed and reviewed the themes and generated clear names for each theme.
<table>
<thead>
<tr>
<th>LOW ADJUSTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme 1: No adjusting at all, with no desire to adjust.</td>
</tr>
<tr>
<td>Theme 2: Some adjusting. The teaching is unchanged, except for some related examples to the specific vocational education.</td>
</tr>
<tr>
<td>Theme 3: More adjusting. The teaching design is adjusted to the specific vocational education.</td>
</tr>
<tr>
<td>Theme 4: Extensive adjusting. The teaching is integrated into the specific vocational education.</td>
</tr>
</tbody>
</table>

| HIGH ADJUSTMENT |

Figure 2. The figure shows the four themes on a scale with a short explanation about how much and in what way the teaching is adjusted to the vocational education programme the students attend.

The themes were placed on a colour scale to symbolise their relationship to each other (Figure 2). Excerpts were chosen to present the results and were translated into English.

This study examined how teachers use their contextual knowledge, curriculum knowledge, and knowledge of students in the choices they make in their teaching about the environmental dimension of sustainable development. This study is limited to examining the influence of the learning context of vocational education. As has been explained above, the learning context is influenced by a multitude of factors, and this is important to keep in mind when reading the results.

Results

Four themes from the thematic analysis were identified from the data. The four themes varied in terms of the extent to which the science teachers adjusted their teaching to the different vocational education the students attended. To symbolise how the adjusting increases, the themes were placed on a colour scale from white to green (see Figure 2). In the first theme, the teachers reasoned that they do not and have no desire to adjust their teaching to the vocational education programme the students attend because it is more important that students gain a holistic perspective of sustainability issues. In the second theme, the teachers adjusted by using some examples related to the students’ vocational education programme; otherwise, the teaching remained unchanged. In the third theme, the teaching was designed to relate to the specific vocational education programme the students attended. In the fourth theme, the science teachers integrated their teaching into the specific vocational education programme.

Theme 1: No adjusting at all, with no desire to adjust

In the first theme, the teachers did not adjust to the specific vocational education their students attended. However, the degree of difficulty could be adjusted to some extent.

Robin: No, it is still the same labs. It is pretty much the same test, but sometimes in teaching, you may have to start at a slightly more basic level with vocational education [compared with university preparatory education]. What do we mean when we say the atmosphere, for example, or talk about gases? What gases are there in the atmosphere? Looking at the bigger picture, the same thing applies; for example, the energy chapter is always the energy chapter regardless.
In the first theme, the teachers also argued that they are not supposed to change their teaching according to which vocational education programme they teach. Jacob argued that all the knowledge requirements in the syllabus have similar importance:

Jacob: No, I do not change the content. Because if I did that, I would lose the opportunity to test more of the abilities for the knowledge requirements relevant to the course.

Lucas argued in favour of having the same teaching in three different vocational education student groups.

Lucas: Concerning sustainable development, I think it is essential to provide a holistic perspective. Just because you are taking the Vehicle and Transport programme, everything should not only be about transportation. Students must also know that there are economic and social points of view as well. Not everything is just about carbon dioxide and climate change, which you might easily think with regard to the Vehicle and Transport programme. It is important that they know that, but there are other things that are at least as necessary, and even though they have chosen a vocational programme, they need to hear the rest of the story as well.

Although different vocational education programmes connect to different aspects of sustainable development, there is still content that is common for the holistic understanding of sustainability issues. For Lucas, it was important to provide students with the economic and social dimensions of sustainable development to help them understand the whole ‘story’ of sustainable development.

Consequently, the teachers intentionally did not adjust their teaching to the vocational education programme that the students attended, because they considered it more important that students would gain a holistic perspective of sustainable development issues.

**Theme 2: some adjusting – the teaching is unchanged, except for some examples related to the specific vocational education**

In the second theme, the teachers adjusted their teaching of the environmental dimension in sustainable development with examples related to the students’ vocational education programme.

Olivia: I often try to give examples that have to do with their future profession. If it is Building and Construction, I might mention zero-energy houses. If it is Vehicle and Transport, I will take examples from transport.

Further, the focus could partly shift, depending on which vocational education programme the teacher taught.

Emma: Regarding the Restaurant Management and Food programme, I would like to focus on food production.

Jessica: They were taught about poisonous plants. I thought it might be good for them to know, considering that they will be working with children when taking the Child and Recreation programme.

Teachers also highlighted the great opportunity the students will have to contribute to sustainability in their future professional life.

Elliot: To make them think about how they themselves can contribute. I have students attending the vocational programme on Electricity and Energy, and they do not always realise they are sitting on a tremendous opportunity to exert influence in their professional life.

Although the teachers did not adjust their teaching to a great extent, they expressed a desire to adjust more to the students’ vocational education programme. They claimed that they cannot do that because of the given conditions. Olivia argued that there was not enough time for it.

Olivia: No, I will be honest. I know you are supposed to do it, but I have not done it much. I think it is hard to catch up with things like that.
Olivia also highlighted that it is difficult, as she teaches many different vocational programmes, and John underscored that it is difficult when students attending different vocational programmes are placed in the same group.

Olivia: I have a lot of vocational education. If I only had vocational education in Building and Construction with many parallel classes, then maybe I could have developed my knowledge even more on these issues, and perhaps I could have designed a whole section on it. Still, now it is not easy to do that.

John: I teach the students on the Sales and Service programme in a separate group, but I teach the students attending the Building and Construction and Restaurant Management and Food programmes together in a group of 30 students.

Consequently, the teachers adjusted their teaching to different vocational programmes in such a way that they gave examples related to the students’ future professional life. They also shifted focus to some extent. Except for this shallow way of adjusting, the teachers reasoned that their teaching was unchanged. However, the teachers expressed a desire to be able to adjust their teaching more to the different vocational programmes their students attend.

**Theme 3: more adjusting – the teaching design is adjusted to the specific vocational education**

In the third theme, the teaching was designed to adjust to the students’ future professions. However, the main content and learning objectives were the same regardless of the vocational education programme. Emelie described how she designed her teaching about the environmental issues of heavy metals. She said that there was an undeveloped plot of land near the school that contained a lot of lead because there had been a factory there before. Her students were given different tasks, depending on which vocational education programme they attended:

Emelie: The students had to understand that there was lead in the ground, what caused it, and what to do about it, and then they had to devise a proposal for action about what this land could be used for, connected to the Child and Recreation programme. I have also done this task linked to the Sales and Service programme, and then they had to come up with proposals connected to that instead. I think linking to the kind of vocational education they are attending is important.

Also, Jim formulated the tasks differently depending on which vocational education programme his students attended. In this way, the students’ focus on sustainable development differed depending on their vocational education programme.

Jim: It has been how I formulate tasks that the students work with concerning sustainable development. The tasks focus on resource utilisation in the Sales and Service programme. As compared to the Child and Recreation programme, where I focus more on social perspectives.

Sara described how she designed her teaching about environmental toxins on the Handicraft programme (majoring in hair and make-up). The students were allowed to bring make-up or hair products from home to examine at school in the science classroom.

Sara: There are a lot of chemicals in different kinds of beauty products, and if you work in a hairdressing salon or with make-up, you are exposed to a lot of that. It often says on the products that it is natural, and many people believe there are no chemicals in them. This is why I think it is important for them to learn about environmental toxins and other chemicals related to their future professions. They need to know about different chemicals in the products they use and how they can affect humans or the environment.

Denise also explained her teaching about environmental toxins, but she adjusted her teaching to fit her students’ vocational education programme. Her students attended the vocational programme on Health and Social Care.

Denise: In the past, we have worked with environmental toxins in the Baltic Sea, but I have switched to pharmaceuticals because it is in line with the students’ vocational education. We look at how pharmaceuticals
in the environment affect aquatic organisms. We usually start with emissions, what kind of medicine it is, and how it affects ecosystems. For example, if the fish are exposed to anti-depressants or some type of psychotropic drug, they change their behaviour. For example, they leave of the shoal and swim alone. You can see the effects on the ecosystem because they become more vulnerable. The next step is how it can affect human health.

The teachers designed their teaching to relate to the specific vocational education programme that the students attended because it might stimulate the students’ interest and be good for their future professional work.

Sara: I want them to immerse themselves in something that feels exciting and interesting to them.

Denise: I think it is important to know for their future professional life, but then there is also this side effect: if it is interesting, you learn better.

Consequently, the teachers adjusted their teaching to their students’ vocational education because they believed it would stimulate their interest and be necessary for their future work. They adjusted the teaching design, for example by introducing different tasks, but the main content and learning objectives were the same regardless of the vocational education.

**Theme four: extensive adjusting – the teaching is integrated into the specific vocational education**

In the fourth theme, the teaching was highly adjusted and integrated into the specific vocational education programme. Charlotte described how she designed her science teaching in different vocational programmes.

Charlotte: In the Vehicle and Transport programme, I almost only work with the internal combustion engine and the catalyst and acidification. I work together with the vehicle teachers. In Building and Construction, I sometimes work with pH values and I pick up stuff in the workshop. The students who will be house builders usually get to work with energy-efficient houses. With the HVAC students, we work on heat pumps and heat exchangers.

Charlotte argued that her strategy was carefully designed to get the students interested in science.

Charlotte: It is to some extent about how they see me. You kind of buy yourself some science points. I can sneak other things into this. I bring what they already know, and then I can explain how a heat pump works theoretically. Then I can also talk about why these refrigerants are not good for the environment or the people themselves when working with them.

Nora described her teaching about climate change related to the Vehicle and Transport programme, which she designed together with the vocational teachers. She expressed her satisfaction and pride in the teaching arrangement.

Nora: In Vehicle and Transport, we have done a project where the students are in groups and have been given two cars: an electric car (or a hybrid car) and a fossil fuel-powered car. Students need to find out how the two cars work, how to connect the different parts to the battery, and how the oil is transported to the car. Then they compare and discuss. For this student group, I have replaced this activity with the energy work that the other groups do. I still talk about climate change and the greenhouse effect because that is what these cars cause. Last autumn, the vehicle teacher and I realised that we have several contact points. After all, this is how you also want the teaching on the other vocational programmes to work. That such collaborations can be found. But it is hard to get started.

Consequently, the teachers highly adjusted and integrated their teaching into their students’ vocational education. They cooperated extensively with the students’ vocational teachers as they co-planned the teaching. They also carried out parts of their instruction in the vocational classrooms – for example, when Nora held her science lessons in the garage where the different cars were kept. Finally, they also used vocational learning materials in their science teaching. For example, Charlotte picked up materials for her science classroom in the workshop, and Nora used the cars as learning materials.
Table 3. Summary of the findings with theme, degree of adjustment, and chosen examples of excerpts.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Degree of adjustment</th>
<th>Example of excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>No adjusting at all, with no desire to adjust.</td>
<td>No adjusting at all.</td>
<td>‘Concerning sustainable development, I think it is essential to provide a holistic perspective… even though they have chosen a vocational programme, they need to hear the rest of the story as well’.</td>
</tr>
<tr>
<td>Some adjusting – the teaching is unchanged, except for some examples related to the specific vocational education.</td>
<td>Some adjusting.</td>
<td>‘I often try to give examples that have to do with their future profession’.</td>
</tr>
<tr>
<td>More adjusting – the teaching design is adjusted to the specific vocational education.</td>
<td>More adjusting.</td>
<td>‘It has been how I formulate tasks that the students work with concerning sustainable development’.</td>
</tr>
<tr>
<td>Extensive adjusting – the teaching is integrated into the specific vocational education.</td>
<td>Extensive adjusting.</td>
<td>‘I work together with the vehicle teachers. ’I pick up stuff in the workshop’.</td>
</tr>
</tbody>
</table>

**Summary of the findings – the learning context of vocational education works as an amplifier for teachers’ PCK**

In summary, the first theme showed that some teachers do not adjust their teaching to the vocational education programme that the students attend. However, in the second, third, and fourth themes, the teachers adjusted their teaching in varying ways and extents to the vocational education programme the students attend. This adjustment proves that the learning context of vocational education works as an amplifier for many teachers’ PCK. The difference between themes two and three is that the teachers adjust, not only by adding some related examples to their teaching, but also by designing the teaching for the specific vocational education programme. Between themes three and four, the difference is that the science teachers in theme four are not fully satisfied with designing their teaching for the student’s vocational education; in addition, they also plan the teaching together with vocational teachers, carry it out to some extent in the premises intended for teaching the profession, and use vocation-specific material in the teaching. Table 3 summarises the findings with chosen examples of excerpts.

**Discussion and implications**

This study’s research question was to examine in what ways science teachers adjust their teaching of the environmental dimension in sustainable development to different vocational education programmes. The results showed that some teachers do not adjust at all, and others adjust in many ways and to varying extents. The teachers also have different thoughts, explanations, and arguments for their stance and implementation of environmental dimensions in their teaching for sustainable development. For most teachers, however, the specific learning context, regarding the circumstances in which the students attend different vocational education programmes, matters. The results indicate that the teachers used their PCK (Gess-Newsome 2015) in making explicit their knowledge of, reasoning behind, and planning for teaching particular content (in this case concerning sustainable development) in a particular way for a particular purpose to particular students for enhanced student outcomes.

In the theoretical framework of PCK and the model of RCM, the learning context acts as an amplifier or a filter for the teachers’ personal and enacted PCK (Carlson et al. 2019). This study showed that vocational education works as an amplifier for many teachers, but to different extents and in different ways. Examples of amplified effects are that teachers embedded their teaching with aspects from the specific vocational education, designed their teaching depending on which vocational education programme their students attended, co-planned the teaching with the vocational teacher, and performed it in the garage with learning tools for that specific vocational education programme. As described above (Table 1), there are several knowledge
categories for PCK (Chan and Hume 2019). The teachers’ curricular knowledge may influence the impact of learning context as an amplifier. This is likely because, in accordance with RCM, curricular knowledge is an integral part of teachers’ knowledge base, which, together with the other aspects of the knowledge base, holds together and permeates teachers’ PCK. Regarding the relatively open writing of the curriculum (Swedish National Agency for Education 2023a, 2023b, 2023c), it is likely that teachers may interpret the curriculum somewhat differently. As described above, the Swedish curriculum has specified learning objectives concerning sustainable development (1) for all upper secondary education, (2) for each specific vocational education programme, and (3) for the science course. The different parts of the curriculum might lead to tension for science teachers who teach vocational education, regarding how to use the limited time for teaching. The question is whether the teachers should give the students a broad and general science education concerning sustainable development or whether they should instead focus on providing the students with as much essential knowledge as possible in sustainable development aimed at their future professional life. This tension can be one reason for the multiple ways science teachers adjust, or do not adjust, their teaching for sustainable development to vocational education, as the results showed.

Studies that capture how science teachers’ contextual knowledge, curricular knowledge, and knowledge of students influence teachers’ planning and teaching in sustainable development in relation to different vocational education programmes have not been done before now. We therefore strongly recommend more research in this direction.

This article is an empirical contribution to the theoretical concept of learning context in RCM. In line with the articles by Qhobela and Kolitsoe Moru (2014), Liu and Xu (2018), Scheuch et al. (2018), and Tay and Yeo (2018), this study focused on the knowledge categories of PCK that we assume are included in the learning context: context, curriculum, and students.

In line with Timm and Barth (2021), we argue that school is an important factor in achieving sustainability and that the global situation for sustainable development is crucial for the future of humanity. Research has indicated that teachers’ PCK affects students’ learning (e.g. Alonzo and Kim 2016; Gess-Newsome et al. 2019; Keller, Neumann, and Fischer 2017; Kunter et al. 2013; Rollnick et al. 2008). However, more research is also needed to see how teachers’ varying PCK in sustainable development affects students’ learning and future professional life.

In addition to the need for continued research about teachers’ PCK in sustainable development, we hope this study can be a complement to the adjacent research field of ESD.

Finally, we also hope this study will provide valuable insights for curriculum developers and that it will inspire science teachers in their continuous development of PCK about the environmental dimension in sustainable development.

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