PROMOTING SUSTAINABLE DEVELOPMENT COMPETENCIES AND TEACHING IN CHEMISTRY EDUCATION AT UNIVERSITY

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ABSTRACT

Promoting sustainable development in university education is the key towards a good and sustainable future. This article presents two research questions of a broader survey study: (i) How are sustainable development skills promoted in university education in the field of chemistry? (ii) What kinds of teaching methods are used in chemistry university education? The teaching context was greenhouse gases. The data consisted of 43 answers from 9 universities' teaching personnel from the field of chemistry. The data was processed through methods of quantitative analysis and qualitative content analysis. In general, learning competencies were considered important. The most often promoted competence in teaching was critical thinking. The respondents used versatile teaching methods, such as critical reading and writing and problem-based learning. The suggestion was made to enhance chemistry university education by raising the acknowledgment of fostering the learning of sustainable development competencies. This should be met by offering education on the topic to teaching personnel. Further research is needed on how higher education teachers can be best supported in exploiting even more versatile teaching methods.

INTRODUCTION

Chemistry education at the university level has a crucial role in enabling a sustainable and carbon-neutral future. Chemistry specialists have a significant role, especially in reducing greenhouse gas emissions. The most significant greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), CFC compounds, and water vapor (Finnish Meteorological Institute, 2021). Because they are an essential factor in climate change, greenhouse gases were chosen as the topic of this study. They should also be a significant part of climate education. In order to reduce greenhouse gases, it is crucial to steer away from the economy and energy that is based on raw fossil materials. At the same time, more efficient ways to recycle carbon must be invented. This change requires substantial reforms in the industry regarding entire value chains, which include, in the case of

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single products, many operators, production processes, transportation, and recycling of materials (Introzzi & Rosskothen, 2017). To enable this change to emerge, university education in the field of chemistry must promote expertise that consists of key competencies. Many future chemistry specialists work in the industrial sector. Future teachers need to know how to promote them in a relevant way in chemistry education.

The key competencies of sustainable development consist of knowledge, skills, and attitudes (Baartman et al., 2007; Wiek et al., 2011). These include, for example, systems thinking, anticipatory thinking, normative competence, strategic competence, and interpersonal competence (Wiek et al., 2011). To reach this goal of sustainable development, teaching must be in line with the purpose. Learning these necessary skills requires learner-centred, collective, praxis-oriented, and through learners discovery (Stererling, 2004).

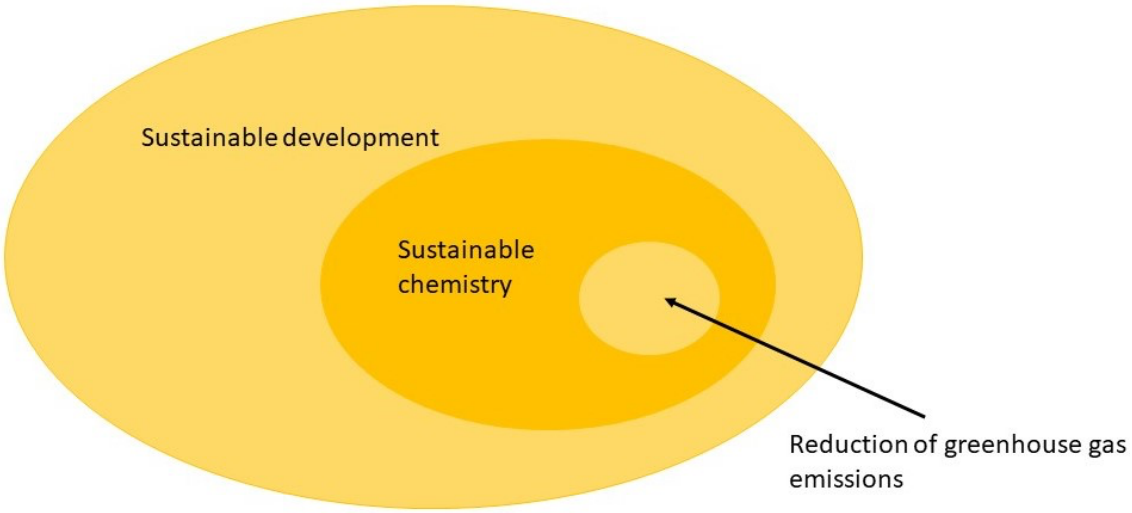
One significant problem in incorporating sustainable development into university teaching programs is that sustainable development has no explicitly defined objective toward which to aim (Thomas, 2009; Wals & Jickling, 2002). It is unknown to us what a sustainable future is like exactly. Thomas defines sustainability as an ambition to fit together opposite sets of values, meaning environment and economic values, between which society positions itself.

To promote the sustainable development competencies in chemistry university education, there is a need for understanding the opportunities and challenges regarding the present state of teaching. This study aims to support this topic's teaching by mapping out the present state through two research questions: (i) How are sustainable development skills promoted in university education in the field of chemistry? (ii) What kinds of teaching methods are used in chemistry university education? The chosen chemistry topic is the reduction of greenhouse gas emissions. This is a central phenomenon in chemistry sustainability education, and there are only a few prior empirical studies on the topic.

Sustainable development, sustainable chemistry, and teaching about them

Because little research has been conducted on the topic of teaching about the reduction of greenhouse gas emissions from the viewpoint of higher education chemistry teaching, the focus of the study was to observe teaching through sustainable development teaching. The reduction of greenhouse gas emissions is one of the central aims of sustainable development.

Sustainable development refers to a type of action where humankind's current needs are satisfied without endangering future generations' opportunity to do the same (WCED, 1987). Sustainable chemistry is often understood as a synonym for green chemistry. Green chemistry was developed in the 1990s in the United States, but in Europe, the term sustainable chemistry was used instead since the word green was associated with green political parties of the political left (Burmeister et al., 2012). Green chemistry is based on systematic planning according to the 12 principles of green chemistry. The aim is to develop substances, syntheses, and processes that are as safe as possible, use as little material as possible, and create only little waste (Anastas, 1998).



Picture 1: The mutual relationship between sustainable development, sustainable chemistry, and reduction of greenhouse gas emissions (Vuorio, 2020)

The Organisation for Economic Co-operation and Development (OECD) defines sustainable chemistry as a scientific concept that aims to develop the efficient use of natural resources in satisfying the need for chemistry products and services, including the planning, production, and usage of efficient, productive, safe, and more environmentally friendly products and processes. The principles of sustainable chemistry also encourage the development of innovations concerning chemicals, processes, and production methods in all sectors, adding performance, and increasing value so that the aims for human health and the well-being of the environment are fulfilled (OECD, n.d.).

The concept of education for sustainable development (ESD) has become established as the term that refers to the teaching of sustainable development. Several other concepts have been proposed for sustainable development teaching as well. For example, Sterling (2004) considers the concept of sustainable education (SE) to be the most comprehensive concept, as it covers the other concepts of sustainable development teaching. According to Sterling, it is also a more accurate term to particularize a fundamental change in the education paradigm (Sterling, 2004).

There are various viewpoints on the implementation of sustainable development in university teaching. For example, Sterling (2004) and Thomas (2009) view that higher education to be consistent with sustainable development requires a profound change in higher education teaching. Thomas argues that as education for sustainable development aims to solve wide-ranging problems, the teaching of it should not be divided into disciplines. Both Thomas and Sterling view the traditional teacher-centred and information transmitting teaching as inefficient on topics of sustainable development.

Fenner et al. (2005) argue that sustainable development should be visible and part of all teaching programs in the University of Cambridge's School of Technology. They suggest it should be implemented both, as a separate introductory courses and part of other courses of the teaching program. According to Cotton et al. (2009), it is not possible to make a complete change in university teaching

in the near future, and thus the focus should be on a so-called second-best approach. This means that university teaching personnel makes little improvements to their teaching whenever possible. Their study was about the University of Plymouth lecturers' views on including sustainable development teaching into their teaching. The study also mapped out challenges that lecturers experienced while incorporating sustainable development into their own courses. The most significant challenges were the relevance of sustainable development for the field of the science taught, although this was very dependent on the lecturer's own interest. It was stated in the study that a lecturer interested in topics on sustainable development considered the topic relevant in their own field, even if the connection was not obvious. As a second challenge, the Cotton and colleagues pointed out, was whether an increase of sustainable development topics in teaching should be guided from above. The third issue was the contradiction between teaching methods in accordance with sustainable development and traditional teaching.

BACKGROUND

Key competencies of sustainable development

Sustainable development competencies or key competencies have been created to compile and arrange the capabilities related to sustainable development. Probably the most well-known is Wiek et al.'s (2011) model which consists of five sustainable development key competencies: systems thinking, anticipatory thinking, normative competence, strategic competence, and interpersonal competence. In like manner, Rieckmann (2012), Lambrechts et al. (2013), and Lozano et al. (2017) based on the two previous, have defined and listed sustainable development competencies. Lozano et al. (2017) ended up with 12 sustainable development competencies: systems thinking; interdisciplinary work; anticipatory thinking; justice, responsibility, and ethics; critical thinking and analysis; interpersonal relations and collaboration; empathy and change of perspective; communication and use of media; strategic action; personal involvement; assessment and evaluation; tolerance for ambiguity and uncertainty.

There are various definitions for the term competence in the field's literature. For most of these definitions, it is common that competence is a combination of skills, knowledge, and attitudes that enable us to carry out a specific task or to solve a problem (Baartman et al., 2007; Voogt & Roblin, 2012; Wiek et al., 2011). An essential characteristic of competence is also the fact that it is not situation-specific, instead, its ability can be applied to the situation on hand (Kauertz et al., 2012). Wiek et al. (2011) view that defining the key competencies required by sustainable development is important so that suitable expertise and teaching can be profiled and assessed.

Brundiers et al. (2020) revised the model of Wiek et al. (2011) to evolve it to become better related to the reality of planning sustainable development courses. In the study, the Delphi method was utilized with 14 sustainable development education specialists around the world. The specialists considered the model of

Wiek and colleagues relevant. However, they also proposed a couple of changes. The changes included adding two or three competencies to the model, setting the normative competence as a predominant competence, and recommending a couple of concrete objectives for learning sustainable development.

Competencies added to the original model included an integrated problem-solving competence that consists of the exploitation of several or all competencies of the model. This includes the identification and application of necessary problem-solving skills. Another added competence was intrapersonal competence or the ability to identify one's inner conditions. This is described to refer to an ability to be conscious of one's own feelings, desires, thoughts, behaviour, and personality as well as the ability to control, motivate, and develop oneself. The third suggested competence was implementation competence, which means the collective ability to put plans and visions into action and to understand the persevering and iterative nature of sustainable development projects. (Brundiers et al., 2020)

An especially significant observation from Brundiers et al. (2020) is that learning sustainable development competencies requires systematic concentration on each competence's concepts, methods, and skills. In addition, when the goal is to enhance the learning of competencies, besides the student, the attention should be on teaching personnel (Brundiers et al., 2020). That way awareness and understanding of the competencies become a part of common knowledge of sustainable development.

Sustainable development and necessary skills

In the sustainable development literature, instead of contents, the focus has been more on necessary skills such as critical, systemic, and reflective thinking; creativity; self-organization, and the ability to make decisions in uncertain situations (Sterling, 2004). The list is long. It includes skills that are believed to be required for conceptualizing future scenarios as pertinent as possible and to attain suitable change. In addition to the above mentioned, the following are highlighted the most: interdisciplinary cooperation, holistic thinking, collaboration and communication skills, problem-solving skills, and anticipatory thinking (Barth et al., 2007; Sipos, 2008; Crofton, 2000; de Haan, 2006; Rowe, 2007). According to UNESCO, central abilities in promoting sustainable development also include sustainability values, understanding of different sets of values, and the ability for lifelong learning (UNESCO Education Sector, 2005).

The skills required by sustainable development are partly the same as 21st-century skills, seen as necessary skills in the 21st-century work-life (Kivunja, 2014). Common, essential skills for these two groupings are critical thinking skills, problem-solving skills, communication skills, and collaboration skills, as well as creative thinking skills. Teaching critical thinking skills has been thought of as an essential part of higher education teaching since the 1980s (Halpern, 1999), and it might be the most researched individual skill or competence. Regardless, the question is also current on whether higher education teachers have enough know-how for teaching critical thinking skills (Janssen et al., 2019; Stedman & Adams, 2012).

Table 1: Skills that were studied in the study: These were chosen from Wiek et al.'s (2010) study.

1. initiative
2. skill to integrate different / opposite values
3. self-reflection skills
4. discussion skills
5. ability for anticipatory thinking / ability to draft future scenarios
6. ability to tolerate uncertainty
7. critical thinking skill
8. creativity
9. motivating others
10. negotiating skills
11. participation
12. ability to carry out interdisciplinary collaboration
13. ability to assess risks
14. grouping skills
15. skill of motivating oneself
16. being a follower
17. being a leader
18. planning and implementation skills
19. responsibility
20. teamwork skills

Teaching methods in accordance with sustainable development

Sustainable development competencies and teaching methods have been studied a little. For example, Lozano and their group (2017) analysed 12 sustainable development competencies and teaching methods and how they support the learning of chosen competencies. They created a matrix on how well the chosen sustainable development teaching methods promote the learning of competencies. In this study, the list of Cotton and Winter's (2010) (table 2) has been used for suitable teaching methods of sustainable development. Lozano et al.'s (2017) and Cotton and Winter's (2010) lists had only two methods in common: case study and problem-based learning.

Table 2: Teaching methods that are suitable for teaching about sustainable development (Cotton & Winter, 2010)

Role-plays and simulations	Helps the learner relate to and gain a deeper understanding of another person's perspective, i.e., different values and interests.
Group discussions	Through group discussions, it is possible to bring forth various viewpoints.
Stimulus activities	For example, familiarizing and looking at series of pictures, videos, or magazine articles to evoke discussion and thinking. Enables bringing forth several viewpoints to the target of critical analysis.

Personal development planning	The learner plans and reflects on their own learning with guidance, for example through a learning diary.
Debates	Requires information retrieval and argument formation from the learner. In a debate, it is also possible to position oneself into the position of people with different values and to observe the situation from various viewpoints.
Case studies	A project is connected to a problem, for example, a research project or a production process. Possibly carried out in collaboration with a company. Gives an overall picture of the topic, a holistic viewpoint. It is possible to emphasize different skills such as self-reflection, research, activity, and participation. Possibility to learn many skills depending on the nature of the task.
Critical reading and writing	The learner learns to identify various motivations that the writer has. Develops critical thinking. Argumentation through various viewpoints helps understand different sets of values and even conceptualize different future outlooks.
Problem-based learning	Requires defining the problem and doing information retrieval on the problem, learners can formulate different solution options and compare thinkable solutions and plans for implementing the solutions. In some situations, the plans can also be implemented. The work is followed by assessment/self-assessment and reflection. Depending on the nature of the work and its implementation, all five different key competencies can be developed potentially.
Modelling good practice	The teacher shows exemplary behaviour, such as turns off the lights etc. In this context, we could think of talking about good model examples and possibly using one's own study as an example, if it is suitable. This mostly has to do with affecting attitudes.
Critical incidents	The students are shown some situation connected to sustainable development and the students ponder on what they would do, what they could do, and what they should do. This task is significant for one's perspective and actions and its moral and ethical evaluation.
Reflexive accounts	A student ponders on their own position in the light of new information regarding sustainable development. This is how they can increase understanding of how the actions of an individual affect the building of a sustainable future.
Fieldwork	A real-life research project that is often organized outdoors in the surrounding neighbourhood. Helps the student understand the meaning of sustainable development in the surrounding environment and the perspective of different operators on the problem.

The following framework of teaching methods, presented in table 3, was used in the study questionnaire. These were chosen from teaching methods recommended by Cotton and Winter (2010).

Table 3: Teaching methods used in the study

1.	An example of good practice, being a good example.
2.	Critical reading and writing
3.	Flipped learning (Students familiarize themselves with the topic before the lesson for example, through videos and tasks.)
4.	Personal development planning (A student plans and reflects on their own learning with guidance, for example, through a learning diary.)
5.	Problem-based learning (Consists of e.g., defining the problem and information retrieval, planning solutions, comparing as well as plans for implementing them and the actual implementation, assessment, and self-assessment.)
6.	Role-plays and simulations (In a role-play, it is possible to e.g., put oneself into the position of the person with opposite interests and to familiarize with their viewpoint)
7.	Group discussion among all course participants
8.	Group discussion in small groups
9.	Stimulus activities (e.g., a video, series of pictures, a newspaper item etc.)
10.	Case study (A project that is connected to a real-life problem, e.g., a research project or planning a production process.)
11.	Debate

DESCRIPTION OF THE STUDY

Participants

The case in this study is representatives of chemistry teaching personnel in Finnish universities, who are leaders of one or several courses related to the chemistry teaching program. In this study, they are referred to as the university's teaching personnel or respondents. In total, 42 responses were obtained, with 18 coming from universities offering science programs and 25 from universities offering technology programs (see Table 4).

The study presented in this article is part of a Master's Thesis (Vuorio, 2020) carried out as commissioned research. The client was the Chemical Industry Federation of Finland (Kemianteollisuus ry).

Data collection

The research data was obtained via an anonymous online survey form. The survey was developed based on previous research findings. Both qualitative and quantitative methods were utilized in data collection, as the aim was to create a comprehensive understanding of the current situation. Using the survey's closed-ended questions, the objective is to generalize the sample studied based on established theory, which is a fundamental aspect of quantitative research (Hirsjärvi et al., 2004).

Table 4: Universities that participated in the study and the number of respondents

University	Number of respondents
Aalto University	13
University of Helsinki	5
University of Eastern Finland	3
University of Jyväskylä	5
LUT University	7
University of Oulu	3
Tampere University	2
University of Turku	3
Åbo Akademi University	2

The objective of this study was to create a comprehensive understanding of the viewpoints of university teaching staff in the field of chemistry. To achieve this, a structured method was selected as the means of data collection, with the aim of reaching as many representatives of the sample as possible. This method involved an online survey, which was distributed to the chemistry teachers of nine Finnish Universities. The survey aimed to gather information on the teaching methods utilized by all chemistry teachers, as well as their attitudes towards teaching skills and values. Therefore, the survey was distributed to all chemistry teachers rather than to teachers of specific courses on the topic. The survey did not collect any personal information from the respondents.

The questionnaire for the study was formulated on the Google Forms platform since it was a familiar platform for the researcher. The questionnaire was compiled in Finnish and translated into English so that the non-Finnish lecturers also had the possibility to answer the questionnaire. The aim was to transmit the questionnaire to the respondents at the beginning of January 2020 through vice deans and associate directors in charge of teaching. They received a link to the questionnaire study via email along with information about the study that they then transmitted to the chemistry teaching personnel at their universities. Because it was not possible to reach all vice deans and associate directors, some chemistry teachers' names were searched in the course information lists of university study guides, and the above-mentioned email was sent to them. Answers were collected during January.

The research questionnaire consisted of both closed-ended and open-ended questions. The benefit of open-ended questions is that respondents can express themselves through their own words (Hirsjärvi et al., 2004). They enable us to observe what was central in the respondent's thinking and what kind of an emotional reaction the topic causes in the respondent and to identify the respondent's reference frames and motivating factors. In addition, open-ended answers can help the interpretation of answers in multiple-choice questions. The benefits of multiple-choice questions include comparability and manageability, they give the respondent ready-made options instead of the respondent having to produce and name options, which makes the answering easier.

The open-ended questions of the research questionnaire were on the interval scale, dichotomous or ordinal scale. The research questionnaire can be viewed in more detail on the following website: https://forms.gle/UwBoTywpa6NG4zQM7.

Data on teaching sustainable development skills

Research question 1, concerning the views of chemistry university teaching personnel on teaching skills, was answered through four questions, of which three were closed-ended and one open-ended. A multiple-choice question (question 23) was used to map out the respondents' attitudes towards promoting the learning of the listed skills (table 1) by asking "Do you aim to teach/develop some of the following skills in addition to content?" A nominal scale with four answer options was used: "I do not know how one could contribute to the learning of this skill.", "I do not pay attention to the learning of this skill in my teaching.", "I believe that this skill develops naturally in university studies." and "I aim to promote the learning of this skill through my teaching methods." Only one option was allowed to be chosen by the respondent. The skills asked were chosen from Wiek et al.'s (2010) study.

The attitude towards promoting the learning of skills was mapped out by the respondents, and whether the development of skills is an objective of teaching was also determined. Skills were chosen from Wiek et al.'s (2010) study that were explicit and fairly unambiguous. In order for the questionnaire not to be too broad, skills that could be viewed as partly overlapping were left out, such as anticipatory thinking and the ability to draft future scenarios. Additionally, skills that would have needed broader definitions to be understood were also excluded, such as holistic and systemic thinking. The skills that were asked in the questionnaire are presented in a table found in the appendix of this study (Appendix 1).

The second question of the part concerning skills (question 24) was a five-point interval scale question that was used to determine how important the respondents consider the aim of developing skills from question 23 to be in university teaching. The third question (question 25) was asked to the respondent to determine if they believe it is possible to affect the development of skills from question 23. Three answer options were provided: "yes", "no" and "yes for some of the mentioned skills and no for some". The last question of this part was an open-ended question, and its aim was to map out whether the aim to promote the learning of skills is also visible in course evaluations.

Data on teaching methods of sustainable development

Research question 2 about the views of the respondents on teaching methods was answered through eight questions (15–22): four of which were closed-ended and four were open-ended questions. A multiple-choice question (question 15) was used to evaluate how much the respondents use the teaching methods mentioned, with a five-point ordinal scale of 1–5: "Not at all", "Little", "Somewhat",

"A lot" and "Very much". The methods asked were chosen from teaching methods (see table 2) recommended by Cotton and Winter (2010). Critical incidents, reflexive accounts, and fieldwork were left out of the teaching methods on the table as they were seen to have a weak connection to topics regarding the reduction of greenhouse gas emissions from the viewpoint of chemistry specialists. On the other hand, fieldwork was seen to be too similar to methods of case study and problem-based learning, and thus their inclusion would have made the answering unnecessarily difficult. The group discussion was divided into discussions in small groups or among all course participants. Additionally, the flipped learning (or flipped classroom) teaching method was included in the list.

Questions 16–18 were open-ended questions. Their purpose was to map out what kind of teaching method the respondents used the most (question 16), what teaching method they would use or what they preferred to use (question 17) and what kinds of practical problems they experience regarding the choosing of teaching methods (question 18). Data on what kinds of teaching methods are usually used in chemistry university education and how the respondents choose the teaching methods, was collected through these questions.

Questions 19, 20, and 22 were multiple-choice questions used to measure interdisciplinary collaboration with outside partners in the respondents' courses and in the teaching programs they represented. Question 21 is an open-ended question, and it focuses on whether the projects mentioned in question 20 are popular among students.

Analysis of data

The results were processed through quantitative analysis methods and qualitative content analysis. The quantitative analysis was done through descriptive statistical methods. Inductive content analysis has been carried out based on the answers to the open-ended questions.

Bar graph presentations were formed for questions related to internal scales, ordinal scales, and nominal scales. The five-point answer options of the ordinal scale question regarding the usage of teaching methods (question 15) were modified into three-point options, so that categories 2 and 3 as well as 4 and 5 were combined. The answers to the nominal scale question mapping out the promotion of the learning of skills (question 23) were presented as a skill-specific vertical bar graph and a horizontal bar graph displaying the sum of percentages of each answer option for all the skills. The answers to question 24, which mapped out the importance of developing skills in university studies, were presented as a vertical bar graph.

Inductive approach was chosen as the method of the content analysis, because there were no previously created categories that were suitable for the analysis. The answers to the open-ended questions were analysed and the answers were classified. Results present in how many responds a certain type of answer appear and a demonstrative example of each type of answers is provided. In the following section, an example of the classification of answers is given.

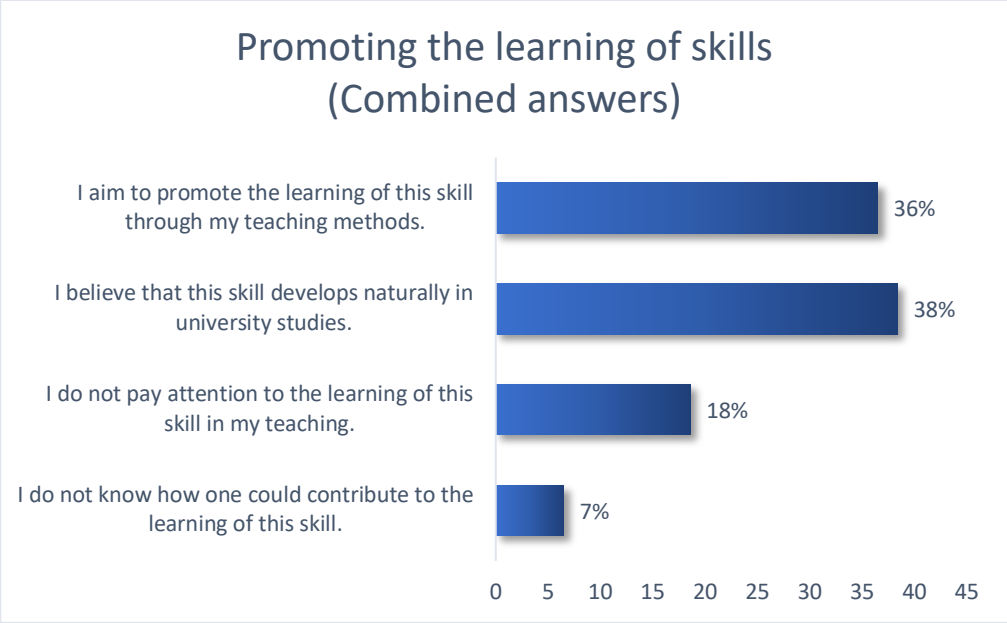
RESULTS

The results are presented one research question at a time. First, the focus is on promoting the learning of skills, and second on the teaching methods used.

Promoting the learning of skills

Development of skills was generally viewed as important in university teaching. Several respondents believed that these skills are developed naturally through university studies.

The attitudes of respondents towards promoting the learning of skills in teaching were mapped out through a closed-ended ordinal scale question (question 23). The results, which have been combined and presented in Table 1, show that the most common answer for the listed skills was "I believe that this skill is develops naturally in university studies." This answer was only two percentage points more common than " I aim to promote the learning of this skill through my teaching methods." The difference is minimal. Only a few respondents did not know how they could contribute to the learning of these skills, and nearly a fifth did not pay attention to them in their teaching.

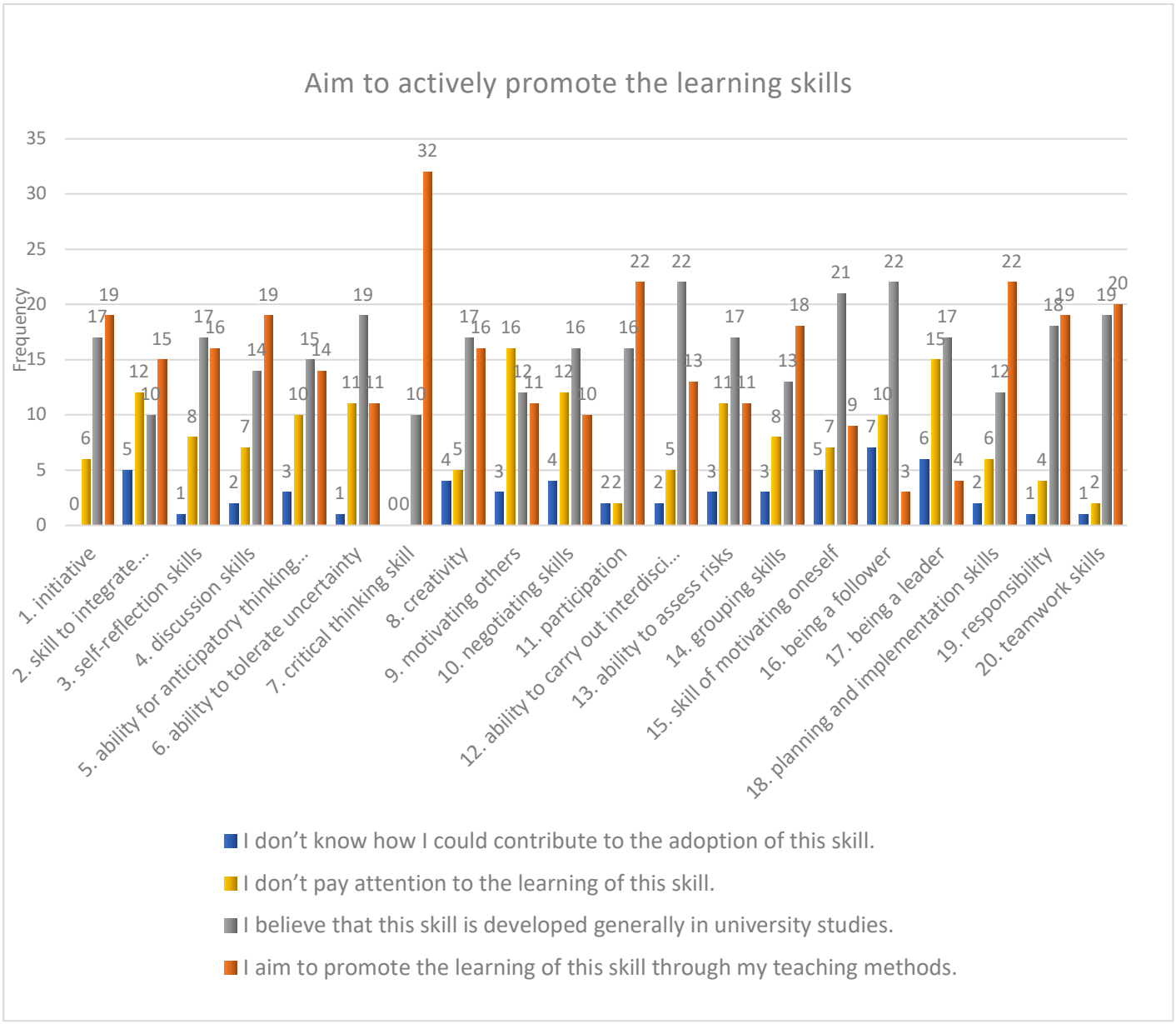


Graph 1: Combined answers to the question "Do you aim to teach/develop some of the following skills in addition to content?" N=42

Most respondents were found to aim to actively promote the learning of nine specific skills in their teaching, with critical thinking being the most mentioned. However, for 10 skills, most respondents believed that they develop naturally during university studies. Only on skill, motivating others, most respondents did not pay attention to the learning of it. The most challenging skills to contribute to the learning of were found to be being a follower and being a leader, but it was

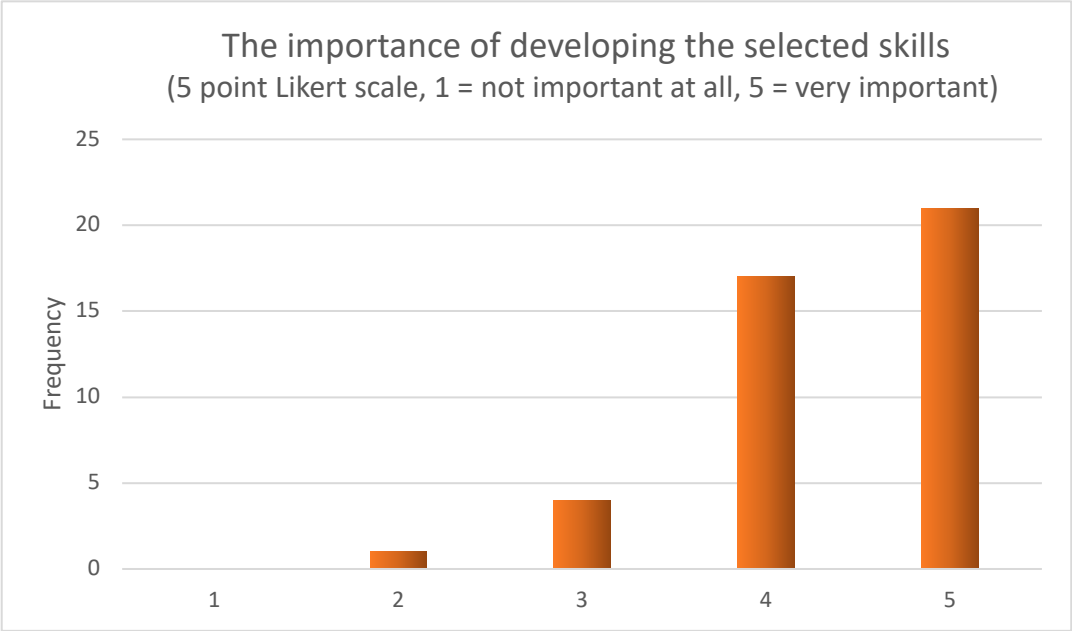
also most common for these skills to be viewed as developing naturally. Only two respondents were found to not aim to promote the learning of any of the skills mentioned through their teaching methods. All answers to the question are presented in graph 2.

The closed-ended questions 24 and 25 were used to determine how important the respondents think the aim to develop skills, listed in the previous question (23), in university teaching is and whether the respondents think that it is possible to contribute to the development of these skills. Finally, with an open-ended question (26), it was inquired whether the respondents take one or more skills into consideration in their course assessment.



Graph 2: Answers to the question "In addition to teaching about subject matter, do you aim to teach / develop some of the following skills?" The number of answers has been illustrated on the y-axis. N=42

From graph 3, it can be observed that most respondents were found to think the learning of skills is important (question 24). More than half of the respondents were observed to view that contributing to learning is possible for all listed skills



(question 23), and the rest of the respondents held this view for some of the skills (question 25). In the course assessment, a substantial portion of the respondents were found to take more than one skill into consideration, but around a quarter of respondents informed that they only measure subject knowledge, and a fifth left the question unanswered. The rest named one skill that they aim to measure in the course assessment.

Graph 3: Answers to the question ”How important do you think it is to aim to develop students’ skills, mentioned in question 23, in university teaching?” The number of answers has been described on the y-axis. N=43

Using of teaching methods

The use of teaching methods was asked with an ordinal scale question 15, where it was mapped out how much respondents use the methods chosen for the research questionnaire (table 3). The results were presented in graph 4, where it can be observed that most of the respondents were found to use different teaching methods in a versatile way.

From graph 4, it is clearly visible that role-playing and debate are used the least. The most popular were found to be modelling good practice as well as critical reading and writing. Also, a fairly large portion of respondents were found to use problem-based learning, stimulus activities and case study much or very much.

Through three open-ended questions, it was mapped out what teaching method or methods the respondents used the most (question 16), what teaching methods

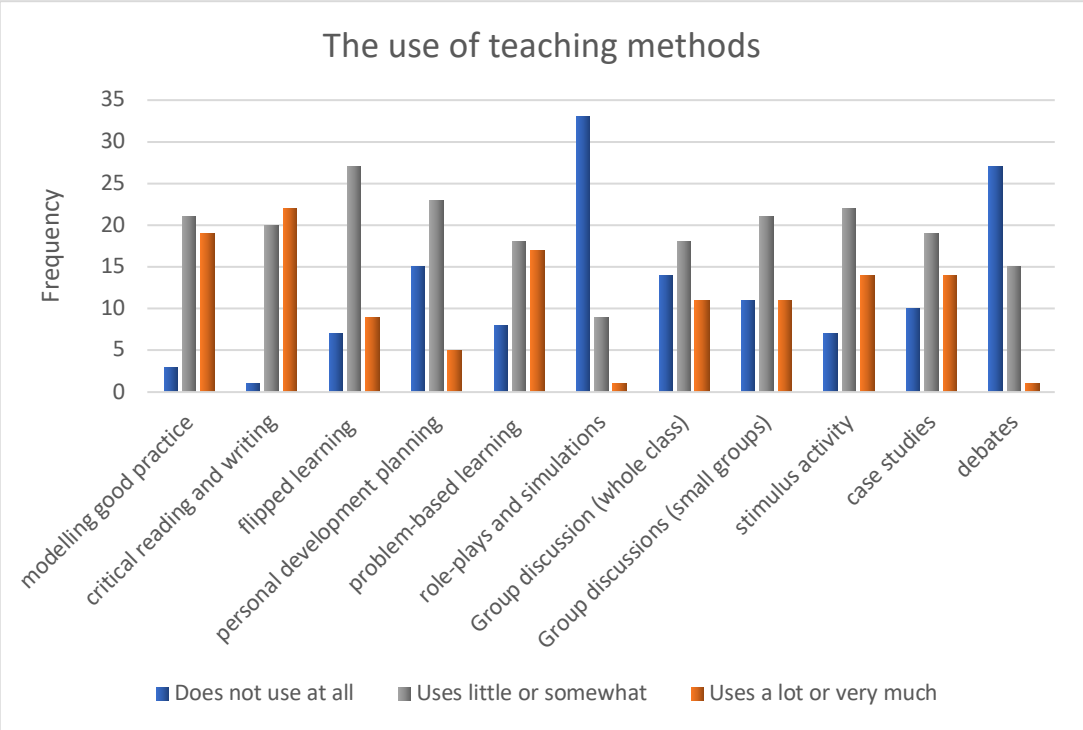
they would use or prefer to use (question 17), and what problems they experience regarding the choosing of teaching methods (question 18) were identified.

Next, the answers to question 16 are presented. 41 answers were acquired to this question. The answers present teaching methods that respondents have named differently than the methods listed in the questionnaire, or broader superordinate terms, such as project work that can include a group of different teaching methods. All answers were considered in the classification of the answers. Most (f=27, 66%) reported lecturing as one of their most used teaching methods, but only a few (f=4, 10%) answered lecturing as being the generally used teaching method. The general combination included lecturing and practice and/or laboratory work (f=12, 29%), as reported by respondent V35.

V6: Traditional lecturing

V35: Lectures, calculation exercise sessions, and laboratory work

8 of the respondents (20%) reported that group work was the most used method. Project work, group work and presentations were used the most by 15 (37%) respondents in their teaching.



Graph 4: Answers to the question ”How much do you use the following teaching methods in your course/courses?” The number of answers has been described on the y-axis. N=43

Discussion or dialogue was used by 4 (10%) respondents. 5 of the respondents (12%) mentioned activating methods. When activation is understood as operation that activates students during lectures, and does not include making exercises or group work, 11 (27%) reported using activating methods the most in their teaching as is visible from answers of respondents 4 and 9. Also, discussions have been included as activating methods in lectures.

> V4: Varied materials and activating questions linked to them.

> V9: Teacher-led teaching in contact sessions and exercises every 20–30 mins during the lecture.

One (2%) respondent highlighted self- and peer evaluation. Learner-cantered working methods are highlighted in the answers of two (5%) respondents, such as is reported by respondent 11.

> V11: Students make presentations either on assigned topics or on their own topics.

Four of the respondents (10%) mentioned a teaching method that follows the ideal learning of skills or competences of sustainable development or that develops these skills, but that are not included in the list in question 15. The answers of respondents 10 and 36 are provided below as an example.

> V10: Group work in multidisciplinary / multicultural teams

> V36: … current situation vs. reflection on the future.

Some respondents reported using very versatile teaching methods:

> V32: Lecture, visiting specialist lectures, electronic questionnaires (Quiz), students' me-we-us – critical reading and making terminology descriptions (over the years), calculation exercises, exam, structured reading task of a scientific article, literature work in groups, a visit to a facility outside of school, continuous electronic assessment as a replacement of an exam.

Question 17 asked what teaching method the respondent uses or would prefer. 36 respondents answered this question. Overall, 11 (31%) respondents mentioned a method that was present in question 15. 5 (14%) respondents marked the flipped learning teaching method, such as respondent 38 indicates below. Two of the respondents do not use it at all in their teaching.

> V38: Flipped learning (I prefer it). I think that it is very efficient.

3 (8%) respondents mentioned case study or problem-based learning. Discussion was mentioned by 3 (8%) respondents. 1 (3%) respondent would like to use self-assessment more.

Question 18 asked the following: what kinds of practical challenges were connected to the choosing of teaching methods. 37 respondents answered this question. 4 participants (11%) did not experience practical challenges in the choosing of teaching methods. Most mentioned aspects were minor resources (f=13,

35%), lack of time (f=11, 30%) and large group sizes (f=9, 24%). The comment of respondent 3 is an example of this:

> V3: Changing/developing the practical implementation takes up an enormous amount of work time that we do not have. Teaching resources available in large-enrolment courses are not enough for small-group instruction.

The next most common reason was reasons caused by students' know-how/skills (f=7, 19%). Also, the excessive workload of students was mentioned (f=3, 8%).

> V8: The thin level of know-how of Finnish people, and the poor English skills of students from abroad.

> V9: There are big student groups and short teaching periods (6 weeks + an assessment period) during the first-year courses, anxious first-year students, giving more versatile feedback. Caused by the mass courses, second-year students' learned reluctance towards anything else than traditional teaching methods (not participating in teaching, not submitting in course pre-assignments or mini projects), including laboratory work into theory courses that leads to students' workload growing easily to a too high with extra assignments.

> V38: Engaging students (challenge about choosing the teaching methods). For example, the challenge of flipped learning is getting the students to do enough work beforehand. A guided learning diary is successful if the student writes it regularly during the entire course.

Two of the respondents mentioned their own digital skills and one mentioned their own skills in general, which can be interpreted as pedagogical competence.

Questions 18, 20 and 22 are closed-ended questions that aim to map out what kinds of interdisciplinary collaboration the respondent carried out in their courses as well as the collaboration between the training program that the respondent represents and with outside partners and other fields of science. Question 21 is an open-ended question that asks whether projects mentioned in question 20 are popular among students.

Regarding questions 19–22, half of the teachers mentioned that they engage in interdisciplinary projects with their students, group work, or other similar activities. Based on the answers, in most universities, collaboration is organized between the students of the training program that the teacher represents and outside partners, such as practical training, working on theses, and other similar practices. Based on the answers, projects inside the university between the training programs that the respondents represent, and other fields of science are organized only in two universities, which are both technical higher education institutes.

DISCUSSION AND CONCLUSION

This study is part of a broader research of teaching competencies related to sustainable development and greenhouse gases. This publication focuses mainly on teaching skills in practice and teaching methods related to this topic. The results are approximate and cannot be generalized based on this single study. However, this study provides insight into how university chemistry teaching staff respond to promoting the learning of skills and using versatile teaching methods.

The respondents generally believed that the learning of skills is important. Most of the respondents focused on actively promoting the learning of critical thinking skills only. Regarding the other skills, a considerable number of the respondents think that the skills developed naturally during university studies. According to Brundiers et al. (2020), the learning of these skills should be systematically promoted. They are not developed naturally in teaching situations. Therefore, it would be essential to provide training for teaching staff about key competencies of sustainable development.

A significant part of chemistry teaching personnel aims to use more diverse teaching methods, even though lecturing is still the most common teaching method. Some respondents thought that traditional lecturing was the most efficient teaching method, especially when there is a lot to learn and limited time. Also, large group sizes and the lack of teaching personnel's time and other resources make it challenging to exploit diverse teaching methods. According to Lozano et al. (2017), it is essential to use versatile teaching methods. Lecturing is not a bad teaching method, even though it is not viewed as promoting the adoption of sustainable development competencies. However, lecturing should not be the only teaching method; it should be one of many methods.

This study reached a basic understanding of the university chemistry teaching personnel's attitude toward promoting skills, pedagogical choices, and challenges related to these. Further research could explore a more detailed mapping of teaching methods chosen by chemistry higher education teachers, of aims chosen for the teaching, and of the implementation of teaching. Research could also examine potential ways to support teachers in using more diverse teaching methods, such as through intervention research.

Lozano et al.'s (2017) and Cotton & Winter's (2010) lists of recommended teaching methods for sustainable development teaching differ significantly from one another. More research is needed on recommended teaching methods for chemistry teaching from the viewpoint of sustainable development, but it would be important to study the teaching methods also from the viewpoint of learning the competencies. Until now, sustainable development competencies and teaching methods have been observed mainly separately.

How to combine teaching methods that support chemistry learning and that promote the learning of competencies is also an important object of further research. Chemistry has its own special characteristics and challenges as a school subject. As chemistry teaching is developed in a direction that supports the learning of

competencies, it is important to prioritize chemistry contents and support the learning of skills.

Sustainable development competencies have not been studied systematically from the viewpoint of chemistry. Defining the sustainable development competencies essential for the field of chemistry would make it easier to plan and assess teaching that follows sustainable development, such as Wiek et al. (2011) emphasize, and would clarify the aims for teaching regarding sustainable development.

However, sustainable development could be viewed as a significant perspective in defining competencies integrated into education. Wiek et al. (2011) view, for example, critical thinking as an important general academic competence to consider in all education. Therefore, it was not included in their model of the key competencies of sustainable development. Intrapersonal competence, the ability to identify self-awareness or one's own inner condition, which was brought forth in Brundiers et al.'s (2020) study could be a similar general competence. A model of chemistry's key competencies could best serve chemistry higher education teaching, where the sustainable perspective is strongly acknowledged.

RELIABILITY AND EVALUATION OF THE STUDY

The validity of the research questionnaire was increased by forming the questionnaire based on earlier research literature, testing it in the research group, and giving it for evaluation to a representative of a collaboration partner. A person who tested the research questionnaire was part of the research group and taught chemistry education courses at the university. Based on her feedback, minor changes were made to the questionnaire. Actual pre-testing was not conducted for the form due to a relatively small target group.

The aim was to send the questionnaire to all persons teaching chemistry at a university through associate directors and vice deans. More answers were received than was expected, but the answer percentage is unknown because the actual size of the target group is unknown. The target group is difficult to define since several fields of technology are problematic to outline as belonging to a specific field of science. It is challenging to determine the representativeness of the sample, as there is no information on the number of courses related to the studied topic area or specifically focused on the topic area. In theory, it would be possible to use teaching programs to map out the courses that are organized, but this idea was abandoned since the precision of course descriptions and availability differed drastically between different universities and degree programs.

The aim has been to improve the reliability of the study by describing clearly how the research data has been collected, what the research sample is like, and by presenting in the report the connection between the questionnaire form and the report. Based on the description, the study could be conducted again.

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APPENDIX 1: The skills presented in the questionnaire have been collected into a table. The skills have been selected from the article of Wiek and colleagues (2011) and it describes to which competence each of the skills in the article have been connected. The first column shows which competence or competencies the researcher group has associated with each skill and the second column presents the skill in question.

Competence	Skill
strategic competence	initiative
normative competence	ability to integrate different / opposite values
strategic competence	self-reflection skills
intrapersonal competence, basic competence	discussion skills
anticipatory thinking competence	ability for anticipatory thinking / ability to draft future scenarios
anticipatory thinking competence	ability to tolerate uncertainty
basic competence	critical thinking skill
anticipatory thinking competence	creativity
intrapersonal competence	motivating others
intrapersonal competence, normative competence	negotiating skills
basic competence	participation
intrapersonal competence	ability to carry out interdisciplinary collaboration
normative competence	ability to assess risks
intrapersonal competence	grouping skills
strategic competence, basic competence	skill of motivating oneself
intrapersonal competence	being a follower
intrapersonal competence	being a leader
strategic competence	planning and implementation skills
normative competence	responsibility
intrapersonal competence	teamwork skills