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# Comparison of German and Japanese student teachers' views on creativity in chemistry class

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## Abstract

Creativity has become an increasingly important skill in today's rapidly changing times, as industries and economies depend upon innovation. It is therefore a requirement for school graduates, especially those who strive towards a technical or scientific career. However creativity has not been integrated into curricula of STEM subjects in many European countries including Germany. To successfully incorporate it in the classroom, it is important to investigate teachers' and student teachers' attitudes towards creativity, as they influence teaching and lesson planning. In cooperation with Kagoshima University, Japan, the possibility to investigate Japanese student teachers' conceptions of creativity and compare them with those of their German colleagues became available. This is of special interest as many differences exist between Germany and Japanese, such as the culture, society and educational system as well as different rankings in PISA and TIMSS. Therefore, the purpose of this study is to investigate, compare and analyse the concepts and views of German and Japanese student teachers. To achieve this, a research instrument, including the creation of concept maps and a questionnaire have been used. In the evaluation of the data, an extensive qualitative analysis of the propositions in the concept maps and statements in the questionnaire were made. These were supported by structural and quantitative analysis. The results show that almost all the student teachers in this study had a positive attitude towards creativity, but there were differences in the understanding and implementation of creativity in the classroom.

**Keywords:** Chemistry education, Creativity, Concept maps, Japan, STEM, Student teachers' views

### Abstract in Japanese

理科教育においては、新しい科学的な発見や技術的な革新を生み出すという意味においても、また、日常生活や職業生活において創意工夫ができるという意味においても、子ども達の創造性を育成することは重要と考えられている。これまで、アメリカなどの欧米諸国、中国や韓国などのアジア諸国の一部では、現職教師や教職課程の学生を対象として、科学および科学教育における創造性に関する認識が調べられてきた。しかしながら、創造性教育の伝統のあるドイツや国際学力調査で上位の日本の教師や子どもの創造性に関する認識 態度は調べられていない。そこで本研究では、ドイツと日本の教職課程の化学(理科)の学生を対象として、化学(理科)および化学授業(理科授業)における創造性に対する態度を調査した。ドイツの教職課程の第2段階に相当する修士課程の学生16名を、日本の教職課程の第1 2学年の学生14名を対象とした。いずれの学生であっても、理科教育に関する専門的な学習をはじめた段階にあった。学生の化学授業(理科授業)における創造性についての態度は、「化学授業(理科授業)における創造性」を中心語とするコンセプトマップとそれを補足する選択式 記述式の質問紙によって探った。学生は、創造性に関連するラベルの有無がある2種類のコンセプトマップを作成した。得られたデータは、コンセプトマップの構造とラベルおよびラベル間の関係に見られる意味内容に着目して分析した。その結果として、化学授業(理科授業)における創造性について、その促進には教師の役割が大きいという認識がドイツと日本の学生に共通して見られた。ドイツの学生のコンセプトマップには、創造性を特徴付けるラベルがより多く見られ、それが構造化されていた。それに対して、日本の学生のコンセプトマップには、必ずしも創造性に関連しているとは言えないラベルも見られ、むしろ化学授業(理科授業)に関するラベルを多く記述する傾向が見られた。今回の調査に限って言えば、日本の教職課程の学生に比べて、ドイツの学生は、化学授業(理科授業)における創造性としての特質などを意識化しており、構造的に捉えられていると言える。ドイツや日本の社会的 文化的な側面での共通点や相違点を視野に入れつつ、理科授業に関する信念や教授行動の実際を含めたさらなる検討が必要である。

### Introduction

In Europe, and especially in Germany, creativity research remains a highly-neglected area even today (Urban, 1991), but, becoming increasingly important in rapidly changing times, as economies depend more and more on innovation. Creativity is therefore a requirement for school graduates, but it is not yet an integral part of education. In order to achieve a successful assimilation in the classroom, there is a need to determine the views and attitudes of teachers and student teachers on the subject. The reason for this is that conceptions of creativity have a great impact on teaching and lesson planning (Newton & Newton, 2009). Similar studies of teachers and student teachers from the USA, Canada, China, India, Korea and some European countries have already been investigated (for an overview of the studies since 1991, see Andiliou & Murphy, 2010 and Kampylis, Berki & SaariLuoma, 2009). Studies looking at the attitude of German teachers and student teachers towards creativity, their understanding and conceptions of it and their will to integrate new ideas in their own class are sorely lacking. This has already led to the completion of a study with German chemistry Master's degree student teachers, (Semmler & Pietzner, 2017).

Based upon an existing relationship with the Kagoshima University in Japan, the possibility to carry out a comparative study of Japanese Bachelor student teachers and their

German colleagues has arisen. This comparison seems to be interesting because there are many differences between Japanese and German culture, their educational systems and their rankings in PISA and TIMSS related to the field of chemistry. The performances of both countries in science are above the OECD average, but Japan is one of the five countries in PISA and TIMSS that has achieved the highest scores and highest achievements in science (International Association for the Evaluation of Educational Achievement, 2012; OECD, 2014). Therefore, it can perhaps be assumed that Japanese teachers and student teachers have different concepts of good chemistry lessons and the integration of creativity in these lessons. In the cultural context, it is also important to investigate whether the social, cultural and educational background of the students influence their views and whether this is expressed in the concept maps. Furthermore, exploring how the students' handle creativity in the context of chemistry and science lessons can lead to new perspectives, which can improve the integration of creativity in class in the other country.

With this background, the purpose of this study is to answer the following research questions:

1) Which views and conceptions on creativity in general and creativity in chemistry classes specifically do German and Japanese chemistry or science student teachers have?

2) How do the conceptions and views on creativity of Japanese and German student teachers differ? And.

3) What connecting factors are arising for teacher training in both countries?

To answer these research questions, a new research instrument was developed, which has already been used in a study of German Master's degree student teachers (Semmler & Pietzner, 2017). It consists of an independent concept map, a concept map with prescribed terms and a short questionnaire. With this research instrument, views, knowledge and attitudes of the student teachers could be investigated. The data collected also gave insights into instructional practice.

## **Theoretical background**

In the following, definitions of creativity as well as some conditions for creative teaching are described. In a second section, the position and understanding of creativity in Japan and Germany are presented.

### **Definition of creativity**

Creativity is a term for which there is no standard definition, many have arisen and some are still relevant today. One such is given by Urban's 4P-E model (Urban, 1995), which states that the four Ps stand for person, product, problem and process, the E for environment. It suggests that creativity can be demonstrated by a person, product, problem or process, and all of them are tied to the social, cultural, political and historical factors of the surrounding environment. The National Advisory Committee on Creative and Cultural Education (NACCCE) in Great Britain provides another for the purpose of implementing creativity in the classroom defining it as "imaginative activity fashioned so as to produce outcomes that are both original and of value" (NACCCE, 1999, p. 30). These two definitions represent the foundation for this study.

Urban's 4P-E model already recognises that creativity is dependent upon cultural factors. In fact, it is influenced by the respective culture as well as the religion. This is one reason for different perceptions in other countries. Culture contains a "system of cognitions, behaviors, customs, values, rules, and symbols" (Lubart, 1999), which is decisive for what is regarded as creative in a society. The definition by NACCCE (1999) corresponds to the perspective of Western countries, while the focus in Eastern countries is on personal fulfillment and the expression of the inner being (Lubart, 1999).

### **Creativity in chemistry classes**

There are only a few studies with relating to creativity in chemistry classes (e.g. Newton & Newton, 2009; Sawyer, 2012). The aspects presented in the following predominantly relate to the integration of creativity in class in general. There are two studies including the investigation of German student teachers' and German chemistry teachers' views on creativity, which are directly related to this study and the authors (Semmler & Pietzner, 2017; Springub, Semmler, Uchinokura & Pietzner, 2017). In Japan, there have been no studies investigating Japanese student teachers' or teachers' views and attitudes towards creativity in class.

There are some factors necessary to implement creativity in the class; new, varied methods and forms of teaching are required to achieve this purpose and are associated with open, student-centered and cooperative teaching strategies (Kind & Kind, 2007). These can include egg races, jigsaw classrooms, learning companies and various types of learning at stations. Diverse media offerings can also help foster creativity in the classroom; modern technologies can provide opportunities for the development of creative skills and new approaches to learning (Fautley & Savage, 2007, p. 84 f.). For teaching chemistry, experiments are of particular importance. Creativity in this area means formulating hypotheses, then planning, carrying out, reflecting upon and revising experiments (Newton & Newton, 2009). This also encompasses the opportunity to design, build and use models independently (Sawyer, 2012, p. 401). In the sciences, the product resulting from creative processes takes a central position (Simonton, 2004, p.15). The students are then able to produce something that is original and of value in the context of the classroom.

### **Creativity and learning environment**

Besides methods and media, creativity can take place in the classroom only in a nurturing learning environment. This includes a stimulating and fear-free classroom atmosphere, valuing even unusual ideas, supporting self-initiated learning and allowing mistakes to be made (Craft, 2005, p. 60; DeHaan, 2009; Fasko, 2001). Knowledge is also a key condition related to any creative work (Weisberg, 1999). Curricula and assessments can hinder the implementation of creativity in the classroom which was confirmed by a study that included European teachers (Cachia & Ferrari, 2010, pp. 28/52).

As mentioned in the introduction, the integration of creativity in the classroom depends to a large extent on the teachers themselves. Besides the planning and designing of a lesson, the attitude, behavior and the skill set of the teacher are important. A positive attitude towards creativity and the person's own creative skills are a prerequisite to implementing creativity in the classroom (NACCCE, 1999, pp. 103 f.). A change in the

traditional role of the teacher is necessary in this context (Safran, 2001). Among other things, a creative behavior can include an open attitude towards pupils' questions and answers, the recognition of different ideas and approaches to solving problems and an increased teacher-student interaction (Craft, 2005, p. 44; Fasko, 2001). Of special importance is the fact that a teacher cannot foster the creative skills of their pupils if they do not recognize and use their own creative abilities (NACCCE, 1999, p. 103 f.).

Fryer and Collings (1991), as well as Kind and Kind (2007) emphasised the inclusion of students in lesson planning and design as an important aspect of the integration of creativity in the classroom. Pupils should be given open tasks that allow them to act autonomously, think independently and to solve problems with different approaches (Craft, 2005, p. 60). It is important that they can develop in assessment-free phases, but an assessment has to take place at a later time (Joubert, 2001). The teacher must activate the students' creativity by facilitating creative processes. To do that there must be a problem that can be solved creatively. The identification of, and solving a problem are parts of the process described by Csikszentmihalyi & Sawyer (2014). It also includes the finding and testing of different approaches, the collection of ideas, the appropriation of knowledge, and a constant reflection and evaluation (Csikszentmihalyi & Sawyer, 2014; DeHaan, 2009; Runco, 2004). In the classroom, the teacher should ensure that students have enough time for such creative processes (Fasko, 2001).

For teachers it is also important to recognise characteristics of creativity and promote them while teaching. Creativity, in general, is characterised by inventiveness, sensitivity to problems, fluidity and flexibility of thinking as well as originality and novelty (Guilford, 1968, pp. 77/82). Adequacy (Runco, 2004), the crossing of borders and rules (Craft, 2003) and the imagination (Kind & Kind, 2007) are also regarded as important characteristics.

### **Differences between Germany and Japan**

This chapter will give a short overview of the differences between the societies, cultures and education systems in Germany and Japan that are relevant for this study.

With respect to the education system, there are fundamental differences between Germany and Japan. The Japanese school system follows the American division of elementary school, junior high school and high school. It is described as a 6–3–3–4 system. This represents the most common educational path according to which students spend six years in elementary school, 3 years in junior high school and 3 years in high school. This can be followed by a Bachelor's degree of 4 years (Frasz & Kato, 1998, p. 315). In Germany, elementary school usually covers grades one to four. The secondary school system is characterised by several educational paths including different leaving certificates that the pupils can attain after the tenth or the thirteenth grade. Gaining a leaving certificate after thirteen years, the pupils are able to attend a university in Germany (KMK, 2017). In Japan, instead of achieving a leaving certificate the pupils must pass an entrance exam to be accepted at a high school or university.

In Germany students usually have to study for 3 years to earn a Bachelor's degree. To become a teacher, they need two more years of academic studies at University to reach the Master's degree. They then have to complete a probationary

teaching post, which takes one and a half years. Usually they study two school subjects at the same time during their academic studies (KMK, 2017). In contrast Japanese student's study only one subject. By finishing the Bachelor's degree students can take an examination to get a teaching certificate that enables them to become a teacher. These certificates depend upon the school type and allow the students to teach in either elementary school, junior high school or high school. For each school type they have to take different courses at the university.

Chemistry is usually taught as one single subject in German schools from grade five or seven onwards. In the Japanese school system, chemistry as a single subject is only available at the start of high school. Prior to that, chemistry is part of the umbrella subject of science along with biology, physics and geosciences and taught from the third grade in elementary school. Regarding the results of PISA and TIMSS, the Japanese pupils have a better understanding of scientific phenomena and it is therefore easier for them to solve a scientific problem. The students' performance in both countries are above OECD average, however, Japan is one of the five countries that has achieved the highest scores and highest achievements in science (International Association for the Evaluation of Educational Achievement, 2012; OECD, 2014).

### **Creativity, economy and social norms**

Creativity plays an important role with respect to the economy, science and technology in both countries. Japan and Germany are leading nations in scientific research according to the Bloomberg Innovation Index, a ranking of countries that measures performance in research and development (Shamah, 2015). Japan is one of the advanced industrial countries in the world, especially regarding natural sciences and engineering. There are many innovative and creative researchers in both countries, but the handling of creativity is different between the countries and depends on social norms (Morris & Leung, 2010). In Germany as in other Western countries it is implicit that people should distinguish themselves from each other. Creativity is therefore focused on the breakthrough of an individual by generating highly original ideas that bring a new technology and improvement. These ideas come to one's mind spontaneously without a long process of thinking and reflecting about a problem (Koh, 2000, pp. 95 f.; Morris & Leung, 2010). In Eastern countries the social norm is that people should maintain harmony in the society (Morris & Leung, 2010). Therefore, creativity in Japan is predominantly group-based and this includes not only the development of ideas and products, but also the creation of harmony within the group (Koh, 2000, pp. 95 f.). The ideas of several individuals are joined and finally united in a new product. Moreover, Japanese creativity is more self-reflecting and thoughtful, which means that a long cognitive and reflecting process leads to an idea that finally can be published. Furthermore, the ideas or solutions to a problem are adaptable to maintain the group's harmony. The Nobel Prize Physics Laureate, Yukawa Hideki, has commented that Japanese people seem to possess some kind of creativity, but they have not pursued, to exposure, their creativity (Yukawa, 1966).

### **Fostering creativity**

In Germany, creativity courses have been offered since the late 1960s. Techniques supporting people developing ideas leading to innovative products have not only already

been tested and used in marketing, but also in other economic areas (Preiser, 2006). To foster adolescents' creativity national and international contests, such as "Jugend forscht" (Youth researches) and "Jugend creativ" (Creative Youth), have been established for pupils to present their own ideas and results to scientific problems. There are no similar events for adolescents in Japanese schools. Nevertheless, the STEM-related policy in Japan emphasizes innovation and creativity (MEXT, 2018a), but is not integrated in the Japanese curriculum for science in primary and lower secondary school, the Course of Study (MEXT, 2018b). It is mentioned in the curriculum for upper secondary school (MEXT, 2018b) as an aim of teaching students. Although creativity should be fostered by competition in school, it is only mentioned superficially in the German curricula for chemistry. Pupils should be introduced to a creative confrontation with chemistry (Niedersächsisches Kultusministerium, 2015). Nevertheless, there have been several attempts to integrate creativity in German classes (Urban, 2004). In relation to this a few detailed methods to implement creative techniques in class are presented in the literature about chemistry education, for example egg races (Borstel & Böhm, 2005) and learning companies (Witteck & Eilks, 2006). In Japan, there are a few studies that have tried to develop science lessons for enhancing creativity in (Fujii et al., 2011). Yumino and Hiraishi (2007) are of the opinion that creativity forms an integral part of the German educational system, but not of the Japanese one. Yumino (2005) tried to introduce creative education from different countries into Japan, Germany is mentioned as an example for creative education.

In Japan, there are some factors that can hinder the promotion of creativity in pupils and its integration into science classes. These include the focus on the entrance examinations to high school. Pupils begin to prepare for these tests in elementary school, therefore, teachers focus their lessons on finding the right solution, memorization and learning important knowledge by heart (Abe, Trelfa, Crystal & Kato, 1998, p. 368; Kim, 2005). In German schools, such strong focus cannot be observed. Furthermore, the integration of Confucianism into society results in a system of expectations towards Japanese adolescents, particularly those of their parents. This can stifle creativity as the pupils have to adapt to the hierarchical structure. Partly due to this the development of their independent thinking skills can be inhibited (Kim, 2005).

### **Description of methods**

To build a comprehensive picture of the views of student teachers, a triangulation (Flick, 2004) of methods was used. The creation of concept maps was combined with answering questions in the questionnaire. Furthermore, two kinds of concept maps were used in this study. There were no guidelines given for the creation of the first concept map, but the second one was created using twenty-two prescribed terms. Therefore, the "Within-Method-Triangulation" along with the "Between-Method-Triangulation" (Flick, 2004) were used here. The research instrument was piloted and used in a previous study of German master's degree students (Semmler & Pietzner, 2017).

Concept maps are structured, two-dimensional representations of knowledge resources, information or ideas about a topic. They consist of terms or rather concepts. Meaningful relationships are produced by grouping corresponding compound words. A connection of

two terms and a linking phrase (e.g. a verb or preposition) is called a “proposition”. These propositions represent separate units of meaning and are therefore part of the cognitive structure. Concept maps are always focused around a main issue (Novak & Cañas, 2007). It is believed that concept mapping corresponds to the knowledge structure in the brain (Yin et al., 2005). Therefore, the cognitive knowledge structure can be visualized using concept maps (Novak & Cañas, 2008). It does not represent a picture of overall knowledge but reveals only an excerpt or snapshot of a person’s knowledge of an issue (Kinchin, 2013).

*“The structure of a map is, therefore, unique to its author, reflecting his/her experiences, beliefs and biases in addition to his/her understanding of a topic. The ability to construct a concept map also illustrates two essential properties of understanding, the representation and the organization of ideas” (Kinchin, Hay & Adams, 2000, 44).*

This method was used so that the participants could present a broad understanding of creativity that was not influenced or pointed in a specific direction by giving a concrete question. Furthermore, they were encouraged to connect their thoughts directly to creativity and among each other.

The research instrument for this study was designed so that the student teachers would develop two concept maps. The participants were given the first part of the research instrument including; a brief introduction, how to create a concept map and how to create the first concept map without prescribed terms. The introduction included an example on which they could orientate on during the exercise. By giving an example, even people with little or no experience of concept maps could understand the method. The participants were asked to create a concept map of their thoughts about creativity and/or creativity in chemistry class. As described above, no guidelines were outlined for the first concept map. This approach is based upon the idea that the students should not be influenced or restricted by suggestion, but that they should express their thoughts freely. After creating and completing the first concept map, the participants received the second part of the research instrument; a second concept map to be created with twenty-two prescribed terms as guidelines, and filling out a questionnaire. Furthermore, the terms “Creativity” and “Creativity in Chemistry Classes” are written in the centre of the empty paper. The terms were extracted from a master concept map, which was created by Semmler & Pietzner (2017) especially for these studies. It represents the current results and trends in creativity and educational research already described above. The terms given in the research instrument as prescribed terms for creating the second concept map are presented in Table 3. The specification of terms is meant to investigate the participants’ understanding in exactly these areas (Novak & Cañas, 2008). In addition, the resulting concept maps are more easily comparable. Similarities and differences in understandings can be quickly determined along with a comparison with the data found in the literature (Kinchin, 2013) is facilitated.

The questionnaire at the end of the research instrument should support the concept maps and collect personal data. The questions were supposed to investigate important aspects of the teachers’ conceptions about creativity, which may have not been expressed in the concept maps clearly enough. The questions relating to creativity were taken from an online questionnaire by Springub (2014), who investigated the views of chemistry teachers about creativity in chemistry classes (Springub, Semmler, Uchino-kura & Pietzner, 2017). The questions were 1) whether promoting creativity is an important goal in chemistry class, 2) if creativity has already been integrated into the

classroom setting, 3) whether creativity should play a major role in the subject's own future teaching, 4) if creativity plays (or played) a role in their chemistry studies, and 5) whether the students would describe themselves as creative. The participants were asked to give additional reasons for the questions 1), 2) and 5). In addition, they were asked to give examples of personal teaching situations in which creativity has played a role.

### Quality criteria

The quality criteria for quantitative research cannot be transferred to qualitative research. Therefore, objectivity, validity and reliability cannot be measured in a traditional way and they are not appropriate for this study, as the research instrument should investigate a person's individual view. The concept maps, which are used to investigate the views, represent only a snapshot of the knowledge and understanding. Therefore, a replication of the study is not possible, and the quality criteria would need to be redefined. The researchers abided by six general quality criteria for qualitative research developed by Mayring (2014, p. 109): documentation of method, interpretation safeguards, proximity to the object, rule-boundedness, communicative validation and triangulation. These quality criteria ensured that care was taken in this article to describe every process step in detail, to present the theoretical background as comprehensively as possible, and to connect different analytical approaches, methods and interpretations. To ensure the research instrument's reliability a group discussion, including PhD students, lecturers and a professor about the method, the data, the evaluation and especially the defining of categories, occurred. All of them have been involved in the process of developing the research instrument and have carried out research in the field of creativity before. The decision to include the questions, another concept map without prescriptions and the reorganization of some propositions were results of this discussion. "Interpretation in groups are a discursive way of producing inter-subjectivity and comprehensibility" (Steinke, 2004, p. 187).

### Description of the sample and implementation of the survey

Table 1 provides an overview of all participants in the study, arranged according to age, sex and origin.

The surveys were carried out at different times and in different countries. The selection of participants was made randomly.

**Table 1** Distribution of the participated students by age, sex and origin

Age	Number of German students		Number of Japanese students	
	female	male	female	male
< 20	1	0	5	3
20–25	5	4	2	4
26–30	0	5	0	0
31–40	0	0	0	0
> 40	1	0	0	0
Total	7	9	7	7
	16		14	

The survey with German student teachers was carried out in January 2016 during the course of a chemistry education seminar at the University of Oldenburg. At the time of the survey, all students were studying a Bachelor's degree programme. The majority of the participants were studying to become teachers for upper secondary school, although one was studying to become a lower secondary school teacher. Ten students were studying in the third to sixth semester and thus within the regular period of study for a Bachelor's degree. Six students had already been studying for more than six semesters. The second subject studied varied widely: Six participants gave mathematics as the second subject, five participants named biology. Other subjects were philosophy/"values and norms", German studies, history and art.

The survey with Japanese student teachers was carried out in October 2015 at the University of Kagoshima during a science seminar. The possibility to carry out the study at the University of Kagoshima occurred as a result of a joint project between this university and the University of Oldenburg. All fourteen Japanese students were studying within the regular duration of study at the time of the survey, with all semesters represented. Most of them had not yet decided on the future school type so all three Japanese school forms, elementary school, junior high school and high school, were represented.

The concept maps and questionnaires carried out by the Japanese students were completed under the supervision of a researcher, but under instructions from their professor. Before implementing the research instrument was first translated into English. The concept map and the prescribed terms were then translated into Japanese in collaboration with the professor. The authors decided to translate only these two elements as it could become too complicated. Therefore, the general information about the study as well as the instructions were translated into Japanese only verbally. However, the students could create the concept maps and fill out the questionnaire in Japanese. These were then translated into English by a Japanese native speaker. With the German students, the survey was carried out without prior instructions, they received the instructions and information in German carrying out the tasks under the supervision of the researcher. The students created the concept maps and filled out the questionnaire in German, which were subsequently translated into English by the authors.

In both cases, the research instrument was handed out in two parts. The first part included a short explanation of the survey, an introduction into the creation of a concept map with an example, and the creation of the first concept map. This first part was given separately, so that the students would not be influenced by information in the following pages. The second part was handed out after all students had completed the first concept map. This part included the creation of a second concept map according to a defined set of twenty-two prescribed terms and a questionnaire to be filled in.

### **Quantitative evaluation**

In the quantitative evaluation the number of terms, propositions, predefined terms used, newly added terms, and unrelated terms were determined and compared according to the origin and gender of the students. These results supported the results of the qualitative evaluation including the structural and the content analysis.

When comparing the results of the first five categories in Table 2, it was noticeable that the numbers are higher for the German students than for the Japanese ones. This

**Table 2** Numbers of different factors in the concept maps, differentiated according to German and Japanese and female (f) and male (m) students (Ø means “in average”)

Category	German students	Japanese students
Number of terms in the concept maps without prescribed terms	13–21	9–31
	Ø 15.6 (f)	Ø 14.9 (f)
	Ø 18 (m)	Ø 15.9 (m)
Number of terms in the concept maps with prescribed terms	12–24	9–24
	Ø 20 (f)	Ø 16.7 (f)
	Ø 18.7 (m)	Ø 17.9 (m)
Number of propositions in the concept maps without prescribed terms	14–47	11–32
	Ø 26.3 (f)	Ø 17 (f)
	Ø 24.4 (m)	Ø 18.6 (m)
Number of propositions in the concept maps with prescribed terms	16–60	9–52
	Ø 31.1 (f)	Ø 21 (f)
	Ø 27.6 (m)	Ø 26.4 (m)
Number of prescribed terms used in the concept maps with prescribed terms	Ø 15.8	Ø 10.1
	Ø 15.6 (f)	Ø 11.6 (f)
	Ø 15 (m)	Ø 9.6 (m)
Number of newly added terms in the concept maps with prescribed terms	33	61
	Ø 2.6 (f)	Ø 2.9 (f)
	Ø 1.7 (m)	Ø 5.9 (m)
Number of less connected terms in the concept maps without prescribed terms	54	62
	Ø 4 (f)	Ø 4.6 (f)
	Ø 2.9 (m)	Ø 4.3 (m)
Number of less connected terms in the concept maps with prescribed terms	75	57
	Ø 6 (f)	Ø 4.3 (f)
	Ø 3.7 (m)	Ø 3.9 (m)

difference is clearly shown in the amount of the created propositions and prescribed terms used. This suggests that it was easier for German students to connect the prescribed terms with their understanding of creativity in general. However, the greater number of less connected terms in the concept maps used with prescribed terms shows that it was difficult for the German students to link them together. Altogether a high number of less connected terms could be found in the concept maps for both groups of students; the structural analysis provides further information on the interconnectedness of the terms.

Table 2 shows that German and Japanese students differ in their use of the prescribed terms. The Japanese students used fewer of them. Thus, many terms were included in the concept maps by only a few or only one student.

The fact that the Japanese students had difficulties assigning the prescribed terms to creativity can also be seen in the high number of newly added terms in these concept maps. Japanese men, especially, exhibit a much higher usage of their own phrases than German men. This suggests that they tend to associate other terms with creativity than the prescribed ones.

Comparison of the variety of phrases in the concept maps with prescribed terms and in those without, yielded the result that it does not vary greatly in both groups of

students. However, the quantity of phrases and propositions increased for the concept maps with prescribed terms from both student groups. This suggests that the prescribed terms lead to new links relating to creativity.

The most frequently and least frequently used terms in the concept maps with prescribed terms can be found in Table 3.

The groups shared only a few terms, for example ‘Teacher’. This seems to represent a key concept role for both student groups in relation to creativity. The same applies to ‘Student’ and ‘Knowledge’, the latter being the most frequently used amongst Japanese students. Similarly, the ‘Product’ was rarely used by both groups, so it does not seem to play an important role for these students.

By contrast, major differences show in using the terms ‘Limits/Rules’, ‘Curriculum’, ‘Cognitive Process’ and ‘Behavior’. These were used by more than half the German students, while the Japanese students rarely established a connection with creativity or the other terms.

With regard to the most frequently used phrases in the concept maps without prescribed terms, there were also differences between the student groups. In these concept maps, the Germans used ‘Creativity in Chemistry Classes’ and ‘Creativity’ with nine and eight mentions respectively. Furthermore, ‘Motivation’ with seven and ‘Experiment’ with six mentions were exhibited. The Japanese students used ‘Experiment’ with nine and ‘Science’ with five mentions, so a basic overlap can be observed only in the

**Table 3** Review of the use of prescribed terms in the concept maps with prescribed terms

Term	German students (N = 16)	Japanese students (N = 14)
Teacher	16	11
Limits/Rules	15	4
Curriculum	15	5
Student <sup>a</sup>	15	10
Idea	14	9
New Perspectives	14	9
Problem	14	8
Media	13	10
Knowledge	13	13
Assessment	11	4
Methods	11	4
Social Environment	11	4
Classroom atmosphere	11	9
Adequacy/Usefulness	10	6
Cognitive Process	10	1
Behaviour	10	1
Ability	9	10
Originality/Innovation	8	10
Reflection	8	1
Social Conventions	7	5
Intrapersonal Characteristics	4	9
Product	4	3

<sup>a</sup>‘Student’ is used in terms of ‘school student’

term “Experiment”; although it plays a greater role in the concept maps of the Japanese students. “Creativity in Chemistry Classes” and “Creativity” were only found in two Japanese concept maps.

### Qualitative evaluation

The material analysed consisted of the participants’ concept maps, the propositions and the completed questionnaires, in tabular form. The qualitative as well as the quantitative evaluation was made by the first author. The results were discussed with the other authors and then modified. All of whom have been involved in the field of creativity in chemistry or science classes (Semmler & Pietzner, 2017; Springub, Semmler, Uchinokura & Pietzner, 2017). Furthermore, the evaluation process in this study was developed by the first author of this article. The purpose of the qualitative analysis was to give an overview of the conceptions, views and attitudes of German and Japanese student teachers by comparing the results with the literature data. Finally, a comparison of the results of German and Japanese student teachers should reveal differences and similarities in the views on creativity. For this purpose, it was useful and appropriate to categorise the data. With this, the results were more comparable and it was easier to reveal knowledge gaps.

### Categories for analysing the concept maps

The analysis of concept maps is based on the category catalog in Table 4. The classification into categories gives an overview of the teachers’ concepts of creativity, so that similarities and differences can be highlighted making it easier to compare the results from German and Japanese student teachers. The catalog represents the result of a previous survey of several runs of analyses of these concept maps (Semmler & Pietzner, 2017), and was carried out using the “inductive category assignment” according to Mayring (2014, pp. 79–83). In this context, the propositions were arranged according to the terms used, for example, verbs such as “lead to”, “cause” or “result in” indicated consequences, and verbs such as “condition”, “need” or “influence” stated conditions and influencing factors. While analysing the data it is possible to modify or expand the categories according to the inductive category assignment. After several rounds of analyses of the data, the category “Creativity in Non-school Activities and in Everyday Life” was added. Examples of propositions for each category are presented in Table 6.

There were also several propositions that could be assigned to a category “Chemistry/ Science education in general”. This has been omitted in the following, since it has no

**Table 4** Categories for evaluation of the concept maps

Creativity in Chemistry Classes	Creativity
Attitude	Individual Definition
Implementation	Influencing Factors on Creativity
Conditions	Characteristics
Obstacles to Implementation	Influencing Factors on General Processes in Class
Consequences and Effects	Creativity in Non-School Activities and in Everyday Life
Pupils’ and Teachers’ Roles	

relation to creativity. The qualitative evaluation is subdivided into a structural and a conceptual analysis.

### Structural analysis

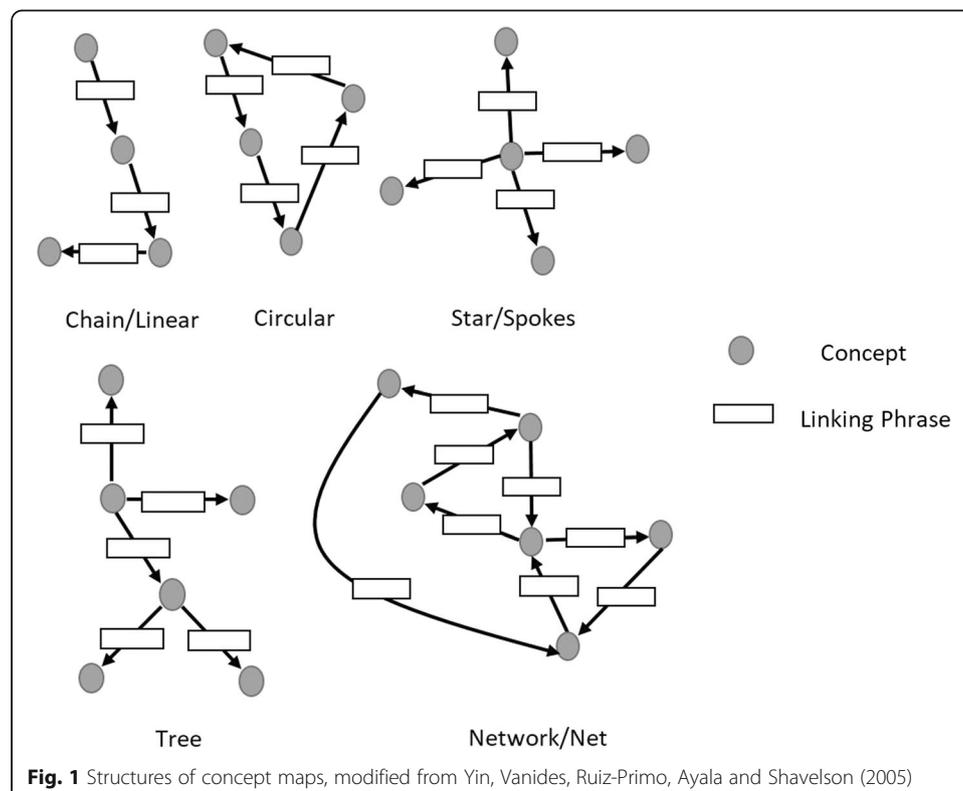
The structural analysis shows qualitative differences between German and Japanese students with respect to structures used and propositions made. The structures reflect the interconnectedness of the terms in the participant's mind, allowing conclusions to be drawn regarding the depth and complexity of a person's understanding of creativity.

The structures of the concept maps were analysed based on the five types shown in Fig. 1.

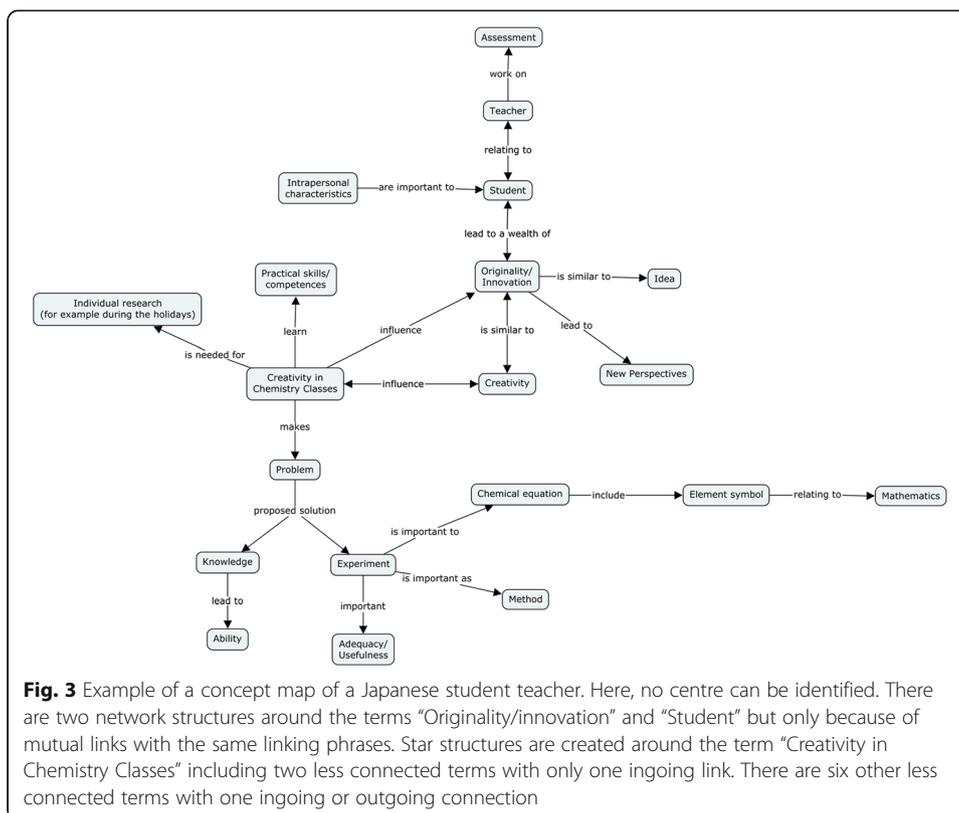
Regarding the concept maps with prescribed terms, six German students recognized "Creativity in Chemistry Classes" and "Creativity" as their centres. In addition, six other German students used "Student" and/or "Teacher" at the centres. These terms lead to the highest number of connections. However, in three concept maps of German students, no centre could be determined.

Only two Japanese students recognized both prescribed terms as centres. Nevertheless, "Creativity in Chemistry Classes" shows the highest number of connections in five concept maps. In another five other concept maps, no centre could be determined. The remaining concept maps showed that there was little agreement among the Japanese students regarding the choice of central terms.

Regarding the centres of the concept maps without prescribed terms, the differences between German and Japanese students were even more apparent. Fourteen of the surveyed German students put "Creativity" or "Creativity in Chemistry Classes" in the centre of their maps. Again, these are the terms with the highest number of







when dealing with the problem “Creativity in Class”. However, they are often accompanied by fewer connected terms that have only one ingoing or outgoing connection. As can be seen in Table 2, there are fewer connected terms in both types of concept maps from both groups. In the concept maps without prescribed terms, however, no agreement could be found with regard to these terms. Similarities could be found in the concept maps with prescribed terms. The most frequently used, but less connected terms by German students are “Adequacy/Usefulness” (6), “New Perspectives” (6), “Ideas” (5), “Media” (5), “Originality/Innovation” (4) and “Social Conventions” (4). Japanese students also rarely used the terms “Media” (5), “Adequacy/Usefulness” (3), “Social Conventions” (3), “Idea” (3) and “Knowledge” (3). Regarding these terms, some students seemed to have problems connecting them to creativity because they made only one connection to the term “Creativity” or to another term that is linked indirectly to creativity.

Although German and Japanese students created similar numbers of star structures, there was a noticeable difference in the numbers of network structures. In the concept maps without prescribed terms of German students, distinctly more network and tree structures could be observed. Both forms represent a form of networked knowledge and profound understanding. Following this difference, it can be assumed that not only did German students find it easier to connect the prescribed terms to creativity (in chemistry classes), but they also had a deeper understanding and more concepts of creativity in the first place. The higher degree of connectedness mirrors a more comprehensive knowledge of creativity.

### Content analysis

The results of the content analysis of the data are presented as examples of propositions made by the German and Japanese student teachers and are presented in Table 6.

### Attitudes toward creativity in chemistry classes

This category includes all the propositions that contain evaluative verbs related to creativity (in chemistry classes). Table 7 provides a comparison of the most important results between German and Japanese students.

The majority of the German students and almost the half the Japanese students had a positive attitude towards creativity in chemistry class. This is shown in verbs such as “promote”, “stimulate”, “open up”, “improve” and “facilitate”, which the students used in respect to creativity in the concept maps. In the maps where an attitude is not identifiable, the students only use neutral, or even no, verbs related to creativity.

Differences between the concept maps of German and Japanese students are apparent. It can be seen in Table 6 that the attitudes towards creativity could be identified from the German students’ maps more frequently. In terms of content, however, the positive statements of the students of both countries proved similar. Both groups, among other things, identified that implementing creativity in the lessons can lead to new perspectives and ideas facilitating the acquisition of knowledge (see Table 6). The only negative statement, from a German student, questioned the usefulness of creativity in chemistry teaching.

In answering the questionnaires, the students showed a positive attitude towards creativity in chemistry teaching. All Japanese, and fourteen of the German students stated that they considered the promotion of creativity among pupils as an important aim in chemistry lessons. Also, eleven German and thirteen Japanese students said they would like creativity to play a greater role in their own future lessons. The reasons for this varied among German students and corresponded largely to the statements in the concept maps. Both groups of students also pointed out the need for creativity in business, science and research. In this context, one German student mentioned that creativity is important because “it gives other pupils a chance, and is needed in economy and research”. A Japanese student wrote that “we need a more mature creativity and especially after graduation for the future of society”.

The students’ reasons for negative answers concerning the allocation of a more significant role and the promotion of creativity, mostly differed. The fact that creativity can take too much time was voiced by both groups, for example “I cannot invest so much time in the topic of creativity”. In addition, a lack of interest by the pupils in a subject (“creativity often exists if there is a big interest in the topic. Not all students have an interest, thus many of them fall by the wayside”) and the slowing rate of learning by focusing on promoting creativity (“if the focus on creativity is too big, the learning speed will be slowed down”) were mentioned.

Regarding their own creativity, the participants of both groups were unsure. Only three Japanese students considered themselves to be creative at all. The reasons for this lack were related to low levels of inspiration and imagination, of talent to develop new ideas and little flexibility in thinking. A Japanese student said, for example: “I have less

**Table 6** Examples of propositions of German and Japanese student teachers (the authors added terms in brackets to make the meaning of the propositions clear)

Category	Examples of propositions of German student teachers	Examples of propositions of Japanese student teachers
Attitude to Creativity in Chemistry Classes	"creativity facilitates acquisition of knowledge" "the students' interest is awakened [by] creativity in chemistry classes"	"creativity in chemistry classes leads to new perspectives" "creativity in chemistry classes leads to knowledge"
Implementation of Creativity in Chemistry Classes	"creativity in chemistry classes [is] included in experiments" "creativity varies variation [of] methods, for example jigsaw classroom [and] learning at stations"	"having questions is solved by experiments" "discussions about scientific phenomena"
Conditions for Creativity in Chemistry Classes	"creativity requires ambitious planning of the teacher" "creativity in chemistry classes needs good classroom atmosphere"	"creativity in chemistry classes uses knowledge" "student leads to creativity in chemistry classes"
Obstacles to the Implementation of Creativity in Chemistry Classes	"curriculum limits creativity in chemistry classes" "creativity in chemistry classes [is] difficult to grade"	"rule is obstacle" "curriculum restricts teacher"
Consequences and Effects of Creativity in Chemistry Classes	"creativity in chemistry classes stimulates independent thinking" "creativity in chemistry classes leads to motivation"	"you gain knowledge [by] creativity in chemistry classes" "creativity in chemistry classes leads to new perspectives"
Students' Role	"students are influenced by social environment [and] social conventions" "students have an influence on classroom atmosphere"	"students influence classroom atmosphere" "students have intrapersonal characteristics"
Teacher's Role	"teacher uses [or] develops methods" "creativity must be [in] teacher"	"teacher should lead to a better classroom atmosphere" "teacher assesses ability"
Individual Definition of Creativity	"creativity is ability" "creativity means no work according to Scheme F"	"creativity is idea" "creativity is similar to originality/innovation"
Influencing Factors on Creativity	"social environment can influence creativity" "cognitive process results in creativity"	"ability leads to differences in creativity" "intrapersonal characteristics influence creativity"
Characteristics of Creativity	"creativity allows new perspectives" "creativity manifests in originality/innovation, among other things"	"creativity leads to originality/innovation" "creativity [is] connected to idea"
Influencing Factors on General Processes in Class	"independence of students to solve problems" "motivation leads to new knowledge"	"self-motivated learning results in knowledge" "media have an influence on classroom atmosphere"
Creativity in Non-school Activities and Everyday Life	"creativity produces inventions [and therefore] individual prestige" "knowledge influences product"	"idea contributes to comfort" "creativity needs development" - "development contributes to the world"

**Table 7** Comparison of the attitudes towards creativity in chemistry classes identified in the concept maps of German students ( $N = 32$ ) and Japanese students ( $N = 28$ )

Attitude	German students	Japanese students
Positive	25	13
Negative	1	0
Not identifiable	6	15

inspiration and fewer good ideas.” Among the German students, eight did not consider themselves creative reasoning that they preferred structures and schemes, that their personal focus was not on the elaboration of experiments and that they lacked diversity of approaches to problem solving as well as inventiveness in developing new ideas. For example, to quote a German student “I fail to find approaches to problem-solving, have only rarely ideas to develop new approaches”.

Positive reasoning partly overlapped between German and Japanese students, for example both mentioned “developing new ideas”. The higher number of positive answers among German students may account for the broader range of reasons. The students described enjoying trying out new methods, to tinker, to create something new, and to question existing concepts.

### **Implementation of creativity in chemistry classes**

In this category, propositions including descriptions of possibilities to implement creativity in chemistry classes using methods and media were classified. Thus, verbs such as “include” and the terms “Methods” and “Media” are important.

Nine Japanese and eight German students described the use of classroom experiments in their concept maps, but they set different priorities. The Japanese students described how creativity is shown by the fact that hypotheses are made and the results from the experiments are compared to these hypotheses, that something new can be shown in experiments, and that experiments are carried out in group work. In the questionnaires, nine Japanese students indicated that creativity had already been integrated into the lessons they had sat in on or conducted. The examples given for creative teaching situations correspond to the propositions in the concept maps described above. They also pointed out that motivation can be created through creativity and the problem-solving process.

By contrast, the German students were of the opinion that creativity appears in exciting experiments related to everyday life and in the setup of experiments in exploratory-developmental teaching. Like the Japanese students, the German ones also pointed to the process of problem solving. Ten German students stated in the questionnaire that creativity had already been integrated into the lessons they had sat in on or conducted. Their examples of creative teaching situations were related to the fact that creativity appears in formulating hypotheses, thinking out experiments, deriving explanations, crafting models, drawing structural formulas and in deriving calculations.

Both student groups included the use of media and methods in their concept maps. Six Japanese students suggested that creativity can be implemented with new methods or teaching materials. They also mentioned that creativity can be generated by the teachers’ questions, by examples from everyday life or writing stories. Five German students took up this aspect of using methods and media mentioning specific tools such as role-playing, jigsaw classrooms, learning stations, mind maps and interdisciplinary project days or weeks. Creativity could also be implemented by setting up chemical equations, identifying chemical properties and phenomena, coming up with new ideas, solving problems and crafting models.

In four concept maps, German students pointed out that creativity appears in the processing and variation of tasks. Two students were of the opinion that creativity can

be implemented by varying social forms, through interdisciplinary teaching and in the planning of lessons. Two Japanese students mentioned that creativity can be achieved by an exchange with others and discussions about scientific phenomena.

#### **Conditions for creativity in chemistry classes**

Propositions categorised here include words such as “influence”, “need” and “require”.

In this category, nine Japanese students stated knowledge and experience as conditions for creativity in chemistry lessons in their concept maps. These include both expertise and problem-solving skills. Only four German students took up the concept of knowledge in their concept maps. Four further German students described the dependence on the teacher. According to them, the teacher should initiate the creative problem-solving process illustrating that creativity requires sophisticated and time-consuming planning skills on the teacher’s part. Two Japanese students also took up this aspect, but did not describe the dependence on the teacher in detail.

In addition, three German, and four Japanese students mentioned the influence of the classroom atmosphere on the implementation of creativity, the assessment of adequacy and usefulness of creativity. A further three German students included the cognitive process and support through the curriculum.

#### **Obstacles to the implementation of creativity in chemistry classes**

Problems and obstacles to the implementation of creativity were rarely mentioned in the concept maps of the Japanese students. The German students gave more extensive and varied descriptions. Propositions including the words “hinder” or “limit” are important for this category. Twelve German students named the curriculum as an obstacle to creativity outlining that the curriculum does not mention it and lacks novelty. Also, as it lays down guidelines for the subject-related contents, the timing and the diversity of methods, it can prove problematic for the implementation of creativity. Only one Japanese student described the curriculum as an obstacle. Limitations and rules in general were pointed out as an obstacle by four German and two Japanese students.

Assessments were mentioned as an impediment to the implementation of creativity by four German and two Japanese students. The concept maps of the German participants indicated that they were unsure how creativity can be assessed within the lessons. The Japanese students also considered assessment to be difficult, as they were of the opinion that it is knowledge that should be assessed, therefore also considering it to limit creativity.

Both student groups saw the person of the teacher as an obstacle. The Germans mentioned the teacher’s age and their attitude towards media supported learning as well as their own limited creativity as hindrances.

Three German students described time constraints and available technical equipment in schools as obstacles.

#### **Consequences and effects of creativity in chemistry classes**

In this category, it is noteworthy that only positive consequences and effects of creativity in Chemistry classes were mentioned by both student groups. As mentioned above,

words such as “promote”, “help” and “improve”, but also “provide” and “lead” used by the students to make the propositions were categorised here.

The German students outlined various consequences and effects. Eight German students described new perspectives as consequences of creativity. These provide different angles and ideas, open up a new way of thinking, and eventually lead to the creation of new products. New perspectives were also included in the concept maps of four Japanese students. However, the Japanese students mentioned knowledge growth and a better understanding of chemical phenomena most frequently. Five students outlined this aspect. Knowledge acquisition was also mentioned by four German students. Creativity is therefore intended to facilitate the acquisition of knowledge, help to remember what was learned, and to foster the generation of knowledge leading to comprehension among pupils.

In addition, six German students described an increase in motivation and interest among the pupils stimulating independent thinking and cognitive processes as results of implementing creativity in chemistry class. The promotion of pupils’ interest in the subject was also taken up by two Japanese students. Five German students mentioned variation and diversity of methods. Pupils’ self-reliance, fun in class, the promotion of problem-solving processes, an improved classroom atmosphere and variety in tuition were listed as results by four German students. Three of them pointed out an advanced use of media and a greater learning success.

#### **Pupils’ and teachers’ roles**

This was the most comprehensive category in the survey, which has already been inferred from the results of the structure analysis. Not only were the terms “Teacher” and “Student” frequently used, but they were often placed in the centre of the concept map. This category showed once again that German students have provided a greater number and variety of answers. Seven German participants mentioned that the classroom situation influences pupils in different ways, particularly intrapersonal characteristics, the pupils’ behaviour and their overall abilities. The participants also listed social environment, classroom atmosphere, teachers, social conventions, knowledge and creativity as factors affecting the pupils. Interestingly, four students thought that the pupils themselves had an influence on the classroom atmosphere and the social environment. Three Japanese also described influences on the pupils; that they can be influenced through adults, media, the classroom atmosphere as well as social conventions.

Eight Japanese students detailed more active tasks by the pupils in their concept maps. In addition to the implementation and development of creativity, this included that the pupils gaining experience, acquiring knowledge, creating products, helping each other, discovering goals and solving problems. By contrast, six participants said that pupils should be taught and evaluated by the teacher and gain knowledge and obtain skills through tuition. In contrast, in five concept maps respectively, German students described that the pupils acquire knowledge and skills and run cognitive processes independently. Four other students mentioned experiments carried out by the pupils. Two other students described that the pupils introduce different ideas in the classroom, and one participant was of the opinion that the pupils should reflect on and evaluate themselves.

In the concept maps of both student groups, references to creativity could be found. Four Japanese students suggested that pupils should implement creativity in the classroom and that this should be one of their characteristics. Five German students wrote that creativity stimulates new perspectives and cognitive processes among pupils, promoting motivation and independence, leading to more fun and variety in the classroom which in turn helps solve problems.

The student teachers mostly concurred on the aspect of pupils' innate abilities. According to four German students, the pupils show different characteristics or competencies, for example knowledge, skills, intrapersonal characteristics, but also a distinct individual creativity. Likewise, five Japanese students described in their concept maps that the pupils tend to differ from each other regarding their knowledge, intrapersonal qualities and skills. New perspectives were also taken up by both student groups, but in different ways: According to three German students, new perspectives can be generated in pupils through creativity and the teacher's initiating function. By contrast, the Japanese students only described the pupils' ability to actively seek new perspectives using creativity.

Different views arose between the German and Japanese students regarding teachers. In ten concept maps from German participants, new methods for chemistry lessons were mentioned, which the teacher could use to implement creativity in class, however, they did not expand upon this. A teacher is supposed to use methods to stimulate cognitive processes, solve problems and impart knowledge, whilst constantly reflecting on and revising them. Teaching methods could be media supported and diverse, however these references were not taken up by the Japanese students in any concept map.

There are hardly any matches in the statements of the Japanese students' maps. Four Japanese students described assessing the pupils' achievements and creating the classroom atmosphere as the teachers' tasks. Three Japanese students mentioned the transfer of knowledge. In addition, according to two Japanese students, the teacher has to teach the limits and rules of society to the pupils.

German students also described the teachers' tasks. Here, some similarities between German and Japanese students could be determined. As with the Japanese students, five German students wrote that the teacher should carry out the assessment. Two German students saw the transfer of knowledge as the teachers' task and three students were of the opinion that the teacher has to set limits and rules. In contrast to the Japanese students, in their concept maps, three German students included lesson planning and two other students the organization of experiments, regular initiation of reflection processes and evaluations, as well as the promotion of creativity in the lessons.

Similarities could also be found regarding the requirements or conditions for creative teaching. Five German students were of the opinion that teachers should use their creativity and have diverse ideas, but also show proficiency in appropriate intrapersonal characteristics. Four Japanese students stated knowledge, appropriateness, usefulness, abilities and inventiveness as requirements for a teacher.

According to three German students, the teacher is also bound by limits and rules, especially those set by the curriculum. Similarly, eight other students mentioned that the teacher must adhere to the specifications set in the curriculum.

Seven German students described the relationship between the teacher and the pupils in their concept maps, the teacher stimulating and motivating the pupils, influencing their behavior.

#### **Individual definition of creativity**

In both groups of students, definitions of creativity could rarely be identified within the concept maps. Three German students described creativity as an ability. With the Japanese students, definitions could only be identified in five concept maps and included the idea that creativity is a quality.

The small number and variety of definitions may be related to the fact that many students said that creativity was not part of their academic studies. Only three German students, who also offered a definition in their concept maps, pointed out that creativity had already been part of their academic studies. Seven Japanese students indicated that creativity had already been part of their academic studies.

#### **Influencing factors on creativity**

Factors influencing creativity were rarely expanded upon in the concept maps of either student groups. Similar to the conditions for implementing creativity in class, the word “influence” used to make propositions in the concept maps is important, but only with regard to creativity in general.

Social environment and the media were presented as influencing factors by three German students and two Japanese students. Again, three German participants mentioned the cognitive process, which should lead to creativity. Two Japanese students also described intrapersonal characteristics and abilities as influences on creativity.

#### **Characteristics of creativity**

In the concept maps, characteristics could be identified in propositions such as “Creativity leads to new products” or “Creativity influences innovations” and were mentioned by both student groups. Originality, innovation and ideas were variously described as characteristics by five German and five Japanese students. In addition, six German students presented new perspectives as an important characteristic of creativity. Only two Japanese students shared this view.

Four German students outlined that creativity is important for problem solving. It is used to provide various possibilities to enhance the ability to solve problems and therefore resolve them more easily. In addition, two German students described the fact that creativity may differ in individuals and show in various ways.

Three Japanese students mentioned in their concept maps that creativity or creative ideas should yield products.

#### **Influencing factors on general processes in class**

This category includes propositions that influence creativity in the general teaching processes and illustrates that the German students gave more extensive and more varied descriptions in their concept maps than Japanese students. The encouragement of motivation, fun and interest were most frequently mentioned by German students. Six participants suggested that those factors can be encouraged by experiments, creative

methods, a playful handling of content, by the independence of the pupils and by rich variety in the classroom. The Japanese students mentioned the pupils' learning behavior in five concept maps. This should result in knowledge and motivation as well as originality and innovation.

The development of knowledge acquisition was mentioned by five German students, facilitated by cognitive processes, experiments, motivation, new perspectives and reflection. In addition, four students outlined the effect of their own reflections, ideas, independence and new perspectives in the problem-solving process.

The impact of the classroom atmosphere, motivation and reflection on the cognitive process, as well as its influence, new perspectives and an extended understanding on the reflection itself were depicted in three concept maps of German students. Three Japanese students described the influence of the classroom atmosphere through media and intrapersonal characteristics. Three Japanese participants stated that new perspectives may create problems as well as new developments.

#### **Creativity in non-school activities and everyday life**

To categorise propositions here, they must refer to non-school activities or everyday life, for example occupations, research or familiar surroundings. Seven Japanese as opposed to only two German students created propositions, (take out) which could be classified under this category. The Germans refer to the use of creativity in technology and for new inventions, the Japanese students made reference to research in their concept maps. Accordingly ideas are intended to initiate developments that help the world and society, innovations may be necessary for the future and interest can lead to research, which may help developing new products. Another Japanese student mentioned that friends and family can lead to new perspectives and a person can gain experience from everyday life situations, which together with knowledge can lead to ideas.

#### **Discussion**

The evaluation of the data revealed many differences between the views of German and Japanese student teachers on creativity. Firstly, the German students created more propositions and network structures connecting more terms to creativity. Obviously, they have more knowledge and a broader, deeper understanding of creativity. It is interesting that many Japanese students created propositions to science and chemistry in general, rather than writing nothing, because there is no connection to creativity. They found difficulty referring to creativity at all, as they hardly used the terms "Creativity" and "Creativity in Chemistry Classes" in the concept maps without prescribed terms. This perhaps results from the Japanese mindset described in the theoretical background. Creativity in Japan is group-based (Koh, 2000; Morris & Leung, 2010). However, here they had to create the concept maps by their own. Maybe they have been conditioned to create ideas and solve problems in a group, so this situation was new and more challenging for the Japanese students than for the German students. In addition, Japanese people are generally more self-reflecting and thoughtful (Koh, 2000), the students may have needed more time to reflect upon their ideas before writing them down. The fact that Japanese students have a less understanding of creativity than the German ones could also relate to the teaching and social situation in Japan. There

are only a few attempts to integrate creativity in the classroom (Fuji et al., 2011), the lessons are focused on traditional teaching methods (Abe, Trelfa, Crystal & Kato, 1998; Kim, 2005) and the adaption to the social conventions (Kim, 2005). Due to the small sample, this is only an assumption and cannot be transferred to other Japanese students.

Against this background, it is remarkable that many Japanese students stated that creativity had already been part of their academic studies. The lack of references to creativity in the concept maps imply that it has not explicitly been made a subject of discussion in lectures, but that the students thought they had become creative by solving problems independently. This is also indicated by the lower use of prescribed terms in the second concept maps. For most Japanese students it was obviously hard to connect the terms with creativity.

Although creativity is not integrated in the German and Japanese curricula of science teaching (MEXT, 2008; Niedersächsisches Kultusministerium, 2015), significantly more German students mentioned the curriculum as an obstacle for integrating creativity in class. In addition, the Japanese students only mentioned a few possibilities to integrate creativity in class. This indicates that they do have a more superficial understanding of creativity than the German students, because it can be assumed that they did not try to use or even think about using creative teaching strategies or methods like jigsaw classrooms or roleplays in their lessons. In this context, the Japanese students can learn to use these methods from the German students.

With respect to the possibilities to implement creativity in chemistry classes, the Japanese students focused on the development of hypotheses, the comparison of those hypotheses with the results of the experiments, and discussions with classmates. Although the development of hypotheses was also an example used by German students, most of the statements went beyond this. The independent work of the pupils, the development of different approaches to solving a problem, the creation of models and a playful approach to the content, among other things, formed the focus with the German students. According to Kind and Kind (2007), Newton and Newton (2009), and Sawyer (2012) these are aspects that lead to the promotion of creativity within pupils. Furthermore, they mentioned the creative process described by Csikszentmihalyi and Sawyer (2014) including the development of ideas, the independent planning and performing of experiments as well as the self-reflection in the process. Only a few of the Japanese students took up these aspects; they merely described the development and discussion of ideas. Instead of that, the Japanese students focused on teaching knowledge. This is an important condition for working creatively (Weisberg, 1999), but it is only a part of the creative process.

Some similarities did appear in the evaluation of the data. Both student groups have a positive attitude towards creativity in chemistry class. This is an appropriate, but also necessary requirement for the integration of creativity into the classroom (NACCCE, 1999; Newton & Newton, 2009). Furthermore, the German and Japanese students agreed in the description of the teacher's role. They viewed the teacher's function as a central part in the integration of creativity in the classroom. The important position of the teacher is also indicated by the fact that this term is one of the most frequently used in the concept maps of both groups. The teacher indeed has an important

influence on creativity in chemistry classes (Craft, 2005; NACCCE, 1999; Safran, 2001). Neither student group recognized the importance of the product, especially in the context of science (Simonton, 2004).

Although a prevailing positive attitude is a requirement for the incorporation of creativity into the classroom, many of the participants did not consider themselves to be creative. However, this is of considerable importance for the integration of creativity into teaching (NACCCE, 1999). Self-confidence in personal creative abilities should be strengthened in further training courses or other advanced courses for both student groups.

The knowledge of the concept of creativity in general seems to require scientific deepening within both student groups. The students rarely mentioned a definition or characteristics of creativity. For teachers it is important to identify creative potential and characteristics in their pupils, so that they can promote and develop them (Craft, 2003; Kind & Kind, 2007; Runco, 2004).

More Japanese than German students are aware of the importance of creativity for the professional world (Sawyer, 2010; Ward, 2007). They highlighted the importance of creativity in independent research even in school. Research by pupils seems to be an important aspect of science in classes, according to some Japanese students in this study. Independent research includes creative processes (Csikszentmihalyi & Sawyer, 2014) and is therefore important for the promotion of the pupils' creativity.

## Conclusion

From the analysis, it is evident that the views on creativity in chemistry classes of German and Japanese students differ from each other. With regard to the cultural context, results from this study indicate that views on creativity are attributable to the different cultures, social norms, teaching habits (and mindsets) in each country. The creation of concept maps also seems to depend on these factors. This poses the question, 'Would the results of the study change if the students create the concept maps in groups?' This could be a good angle from which to carry out another investigation of German and Japanese students or teachers.

Nevertheless, the integration of creativity in the concept maps indicates how intensely German and Japanese students have dealt with creativity and reflects that knowledge of the topic differs. There is great consensus on the teachers' role as to the implementation of creativity in class. The quantitative evaluation and the structure analysis imply that it was much easier for German students to bring their ideas of creativity into a concept map and to connect the prescribed terms with creativity. Not only did the German students use more prescribed terms, but they also created more network structures and they created more varied statements in the concept maps in almost all relevant categories. This implies a more complex connectedness and a deeper understanding of creativity.

The positive, open-minded attitude towards creativity is not only an appropriate prerequisite to integrate creativity in the classroom, but also an indication that both student groups know the importance of creativity and creative skills in pupils for their professional career. The Japanese students described this aspect more often, they have a better understanding of using creativity in scientific and technical professions. In this context, it is surprising that Japan is one of the leading nations in scientific research,

but creativity seems to play a subordinate role in science classes, according to the students' statements in this study. This suggests that it would be extremely interesting to carry out another investigation.

Regarding the connecting factors of teacher training or lectures, it can be seen that the Japanese students can absorb many ideas on how to stimulate and implement creativity in class from the German students. Both cadres have to develop self confidence in their creative skills perhaps at training courses, so that they may be good examples of creative behaviour. All the students need to improve their knowledge of creativity in general, so that they can identify characteristics and potential in their pupils and assess the adequacy of methods along with their teaching strategies. German students need a better understanding of the importance of creativity for the professional world. They can learn the role of independent research from Japanese students, which seems to be an important part of education in Japan.

#### Abbreviations

PISA: Programme for International Student Assessment; TIMSS: Trends in International Mathematics and Science Study; USA: United States of America

#### Availability of data and materials

The authors do not agree to share their data because of data protection reasons.

#### Authors' contributions

LS made substantial contributions to the collection of data and the evaluation and interpretation of data, drafted and revised the article. SU was responsible for the translation of the test instrument into Japanese and the communication with the Japanese participants. VP contributed in the evaluation of data and revised the article critically. All authors contributed in the research design and the development of the test instrument. They read and approved the final manuscript.

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#### Competing interests

The authors declare that they have no competing interests.

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