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The concept map as a substitute for lectures: Effects on student performance and mental health

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Additional information is available at the end of the article

Abstract: In comparison with traditional lectures, active learning methods have the potential to foster learner agency and consequently raise academic performance. However, these methods are often applied with little knowledge about their effectiveness. In this study, we introduced two concept maps in an undergraduate cell biology course, to investigate their effect on student performance, but also mental health, in a quasi-experimental setup. By implementing group tasks into the work, we aimed to reduce feelings of loneliness among the participants, a common phenomenon among students in the study country. We evaluated the effects of the concept maps via exam grades and in an anonymous student survey. Here, we found no increase in student performance after introduction of the active learning task. Students also did not report improvements in their feelings of loneliness. We conclude that this active learning method did not detectably improve student performance or mental health, a result which does not conform to the popular perception of positive effects from active learning. The survey revealed that students do not have a preference for either active learning or traditional lectures, however, the students experienced that the concept map helped them to describe, explain and hypothesize about the topics. Overall, this shows that the concept map method is a valid alternative to traditional lectures, since students perform equally between both learning approaches.

Subjects: Cell Biology; Molecular Biology

Keywords: Active learning; deep learning; concept maps; student mental health; higher education

1. Introduction

The use of active learning methods has the potential to improve student performance (Deslauriers & Wieman, 2011; Deslauriers et al., 2019; Freeman et al., 2014), and currently the application of such methods within higher education is actively developed and researched. Active learning methods come in different formats and gradations, but all share a strong emphasis on the students pursuing knowledge and skills themselves. This stands in contrast to students passively absorbing and accepting information presented in a classical lecture; which, in the country where the study was made, usually refers to a lecture given by a single teacher, standing in front of the

class and, though often allowing questions and other limited input from the students, dominates the lecture, monopolising speaking time and thematical input. In contrast the primary goal of active teaching is to invoke deep learning in students by encouraging them to describe, question, explain or hypothesize about a study topic (Biggs & Tang, 1999), so that they develop a personal understanding of the subject, have active interactions with the content, and relate it to new ideas and previous knowledge (Harlen & James, 1997).

Despite the effectiveness of correctly implemented active learning methods, students might experience the misconception that they actually learn less than peers following traditional passive learning methods (Deslauriers et al., 2019). For this reason, it is important to find out how to reassure students effectively about the usefulness of such methods, and how to increase active participation before implementing them (Finelli et al., 2018; Shekhar et al., 2019). Importantly, not only students experience insecurities related to active learning. Teachers may be sceptical of implementing new active teaching methods because they are concerned that this will be met with student resistance. However, teachers possibly overestimate the actual resistance, with self-reports of students revealing a generally positive attitude to the implemented method (Andrews et al., 2020).

For the students, active learning methods potentially have an additional benefit that has not received as much attention yet; improved student emotional health. The years studying for a bachelor's or master's degree can be a psychologically demanding period, especially as many combine their studies with a full- or part-time job. Many may have started living on their own and often they have moved to a new location with neither friends nor family. In a survey conducted in Norway in 2018, 30 % of students indicated that they sometimes, or often, felt lonely (Knapstad et al., 2018). Loneliness has been described as the experience of emotional and social isolation, it is a gnawing chronic disease without redeeming features (Weiss, 1973). Poor mental health is associated with lower student performance (Ansari & Stock, 2010; Duffy et al., 2020; Duncan et al., 2021), so loneliness may negatively affect both the student and the educational institute, as the emotional health and career prospects of students will suffer, and university investment in the student may not lead to any academic outcome. As the experience of loneliness in students can be expected to be highest during the first year of a study programme, due to many of them moving to a new location, often without prior social acquaintance, it is important for universities to consider appropriate support. Active learning methods that stimulate working in groups with new people might contribute to students initiating the first personal informal conversations, essential for establishing new interpersonal relationships.

One active learning method that allows for active group work is the concept map (Figure 1). This learning method was introduced in the nineteen-eighties (Novak & Godwin, 1984) and is aimed at the active construction of knowledge by the learner. The core idea of a concept map is that students use a graphic tool to structure their knowledge, which then assists them in establishing cross-links within a certain topic. It has been shown that the use of concept maps has the potential to improve learning outcomes and grades (Aliyari et al., 2019; Bergan-Roller et al., 2020; Garwood et al., 2018; Jaafarpour et al., 2016). However, the exact application and format of a concept map can vary. Students may be motivated to create a concept map themselves, where they start with an empty sheet and construct it based on the lectures they attended, or the topics they have read. Another approach is to provide a concept map skeleton that specifically leads the students through course material and expected learning outcomes, but that also requires their own input. In both cases it is possible to implement additional group work where students assess and discuss the concept maps of their peers.

Here, we examine whether the implementation of concept maps in combination with group work has an effect on student performance, as well as feelings of loneliness and mental health. We introduced a concept map-based learning method in a Biochemistry and Cell Biology course at the Faculty of Biosciences and Aquaculture, Nord University, Bodø, Norway. This course is mandatory

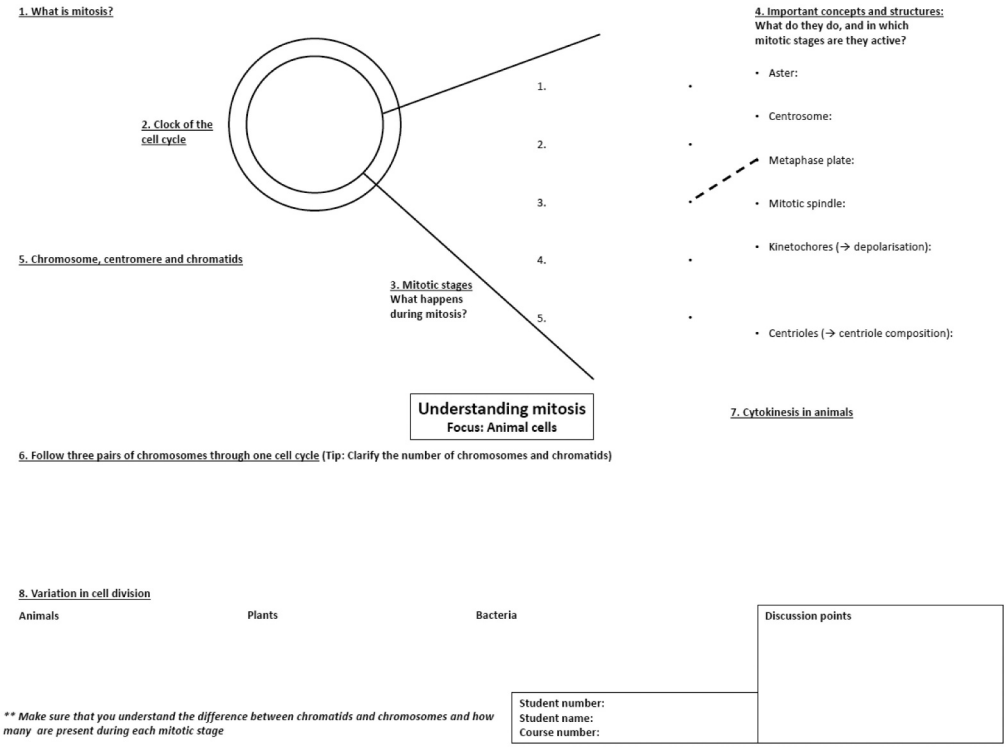

Figure 1. A concept map that was used for teaching the topic of mitosis to students participating in a Biochemistry and Cell Biology course in the first year of a three-year biology bachelor in Norway. Each student was provided with a paper version of the concept map in A3 format (297 × 420 mm) and font size 12 (Figure S1, Supplementary Materials). Note the spelling mistake in exercise number four, where "depolarisation" should be "depolymerisation". This mistake was clarified to the students orally.

within the curriculum of the international bachelor's programme in biology and animal science, and is offered within the second half of the first study year. It has previously been shown that the introduction of concept map-based learning in Biology related courses has the potential to improve student performance (Bramwell Lalor & Rainford, 2014; Brinkerhoff & Booth, 2013; Passmore et al., 2011; Sakiyo & Waziri, 2015), but to the authors knowledge the potential effects on reducing student loneliness has not been tested before. Participating students have various backgrounds, European and non-European, and the course is taught in English. In our approach, we supplied students with the skeleton of two concept maps, covering specific parts of the curriculum (Figure S1, Supplementary Materials), that were required to be filled in by students, followed by group discussions. We evaluated the learning outcome based on student grades, and via a survey examined possible positive effects of the associated group work on loneliness.

2. Methods

2.1. Overall study design

The concept map method was used in a Biochemistry and Cell Biology course, taught in the first year of two three-year biology and animal science bachelor programmes, as well as an exchange programme. To the authors' knowledge, this was the first time this teaching method was used at the faculty.

The quasi-experimental study design included two student cohorts (2018 and 2019), which were taught four different topics (meiosis, mitosis, metabolism, and cell organization) in two different learning designs. In the case of the first student cohort (2018), all four topics were taught via classical lectures of 90 (2 × 45) minutes each. In the case of the second cohort (2019), two topics (meiosis and mitosis) were taught via two individual concept maps, whereas the two remaining topics (metabolism and cell organization) were taught via classical lectures. For the topics taught via classical lectures, lectures took 90 (2 × 45) minutes each, whereas for the topics taught via concept map, short introductory lectures (max. 10 minutes) were given, followed by concept map

work (see below for details). In addition, in both years the two topics covered by the concept maps were each addressed in an individual lab session. The person responsible for the course, and teachers for the lectures, remained the same in both years.

2.2. Concept map work

The concept maps covered two topics, first mitosis (Figure 1), followed by meiosis (Figure S1, Supplementary Materials). Students were instructed to fill in the concept maps "individually with the help of the class book, online resources, etc. ``The goal is that you develop and understand the concept [of the topic] as a whole, and not as individual facts. Therefore, feel free to work on the topic in your own way!"

Students were given ten working days to fill out the first, and 15 days to fill out the second concept map. These were then handed in to the teacher, checked for completeness, and discussed afterwards in randomly assigned groups of six to seven students, in two group sessions of 45 to 90 minutes. Group sessions were supervised by teaching assistants. Only minor input was given to student discussions during group sessions. Hand-in of concept maps and participation in group work were mandatory.

One question in the maps was especially designed to enable evaluation of student performance by the teacher within one minute, to keep their time investment low, while at the same time enabling them to assess whether students had grasped the most important aspect of the study topic correctly, and to give feedback on their learning success (Figure 1, Question 6). For this, students were asked to follow three pairs of chromosomes through one cell cycle, while clarifying the number of chromosomes and chromatids during this process—a task showing directly whether the student understood the main concept of mitosis or meiosis. Students were then given feedback via a score of one to three, a score of one meaning the student's answer lacked fundamental information, and a score of three indicating a full and completely correct answer.

2.3. Evaluation

To assess the effect of concept maps, students were given the same written exam in both study years. The contents of three exam questions covered the topic ´cell organization´ that was taught via lectures for both student cohorts ("question lecture"), whereas the topic for another four questions were taught via lectures to the first, and via concept maps to the second, cohort ("question concept map", topics mitosis and meiosis). Grades were combined into one grade for "question lecture", and one grade for "question concept map". Another twelve exam questions addressed the topic ´metabolism´, taught via classical lectures, but were not used for comparing ´grades from the two teaching methods, as this topic was taught by a different teacher. However, the twelve questions addressing ´metabolism´ were combined into a single grade, entered into the overall exam grade with the same weight as grades for "question lecture" and "question concept map".

This exam design resulted in data which allowed control for possible year-to-year variation in overall student performance via "question lecture", while comparing the teaching efficiency between lectures and concept maps via "question concept maps". Overall exam grades were also compared between the two cohorts. Grading was scaled from highest (A) to lowest (F), with E as the minimum pass grade and the permittance of half grades.

To evaluate students´ reception of the new teaching method, and the effects on loneliness, an anonymous student survey of the second student cohort was taken at the course end, asking for student perception of their learning success with the concept map, their appreciation of the concept map, and the associated group work, as well as perception of changes in their overall, emotional, and social loneliness (Table 1; Table S1, Supplementary Materials) (de Jong Gierveld & van Tilburg, 2006). The survey was constructed as a questionnaire, and survey answers were given

Table 1. Part of a student survey for the evaluation of two teaching methods (classical lectures or concept maps) as well as related group work. Only the questions are presented. Section a and C were answered via a Likert scale ("Strongly disagree/Disagree/Neutral/Agree/Strongly agree"). Section B was answered via three options ("Lectures/Concept maps/No preference", B.1), or freely via a text box (B.2). Section C follows a modified version of the survey by de Jong Gierveld and van Tilburg (2006). The full survey is presented in Table S1 in Supplementary Materials

A.
I feel like I have understood the topics covered by the concept maps.
I feel like I can memorize the topics covered by the concept maps.
I feel like I can describe the topics covered by the concept maps.
I feel like I can explain the topics covered by the concept maps.
I feel like I can hypothesize about the topics covered by the concept maps, e.g. why mitosis could have gone wrong under certain circumstances.
The concept maps gave me the freedom to explore the topics in my own pace.
The concept maps gave me the freedom to explore the topics in my own way.
B.
1. My preference for learning about theoretical concepts is through:
2. If you have a preference, why did you prefer either the concept maps or lectures?
C.
The group work improved my general sense of meaningfulness at Nord University.
The group work improved my general sense of there being plenty of people I can rely on when I have problems at Nord University.
The group work improved my general sense of there being many people I can trust completely at Nord University.
The group work improved my general sense of there being enough people I feel close to at Nord University.
The group work improved my general sense of me feeling accepted at Nord University.
The group work improved my general sense of me feeling part of the Nord University community.
The group work improved my general sense of feeling I belong to Nord University.
The group work resulted in me getting to know other people better.

via a Likert scale with five categories ("Strongly disagree/Disagree/Neutral/Agree/Strongly agree"), freely via a text box, or as a multiple choice answer (Table S1, Supplementary Materials).

2.4. Participants

In the first cohort, 55 students participated in the course, four of which did not take the exam. In the second study year, 76 students participated in the course, with ten not showing up for the exam. Of participants in the second study year, 45 answered the student survey. Since the survey was anonymous, it is unknow how many respondents participated in the exam, and vice versa. Furthermore, consent of the participants was not needed as all data was collected anonymously, and in consent with national ethical guidelines and laws.

2.5. Analysis

Prior to analysis, grades were transformed from alphabetical (F-A, including half grades) to numerical scores (1–10). In order to verify if the two cohorts on average performed equally, we first checked for differences in student performance between years via the exam question taught solely through lectures ("question lecture"). For this, as the data was unpaired and non-parametric, a two-sided Mann-Whitney U test was used. Exam grades were then analysed for significant changes in performance after the introduction of the concept map, via the exam question taught through lectures to the first, and concept maps to the second, cohort ("question concept maps"). For this, one-sided Mann-Whitney U tests were used, once for the overall exam grade, and once

for"question concept maps". The Mann-Whitney U tests involved the alternative hypothesis that grades had improved.

For survey answers, the Likert scale categories were first converted into a binary response by classifying "agree" and "strongly agree" into positive feedback, and "neutral", "disagree" and "strongly disagree" into negative feedback, regarding how the students appreciated the concept maps and connected group work, their learning success with them, as well as changes in their loneliness (Table S1A & S1C, Supplementary Materials). In cases where answers lay exactly between two categories on the Likert scale, the less positive opinion was taken. A one-sided exact binomial test was then performed, to test the probability of positive feedback against the expected probability of 2/5. For the question whether the students preferred either concept maps or lectures, or had no preference, the probability of students preferring one of the teaching methods was tested against the expected probability of 1/3, tested for the two teaching methods separately and taking the preference of neither, or the non-focal teaching method, as a negative answer.

Furthermore, a word cloud was constructed for the text box question which asked for the reasons students preferred either concept map, lecture, or both. The word cloud was filtered for common phrases via the R-package "wordcloud", and visualized using the package "wordcloud2". All statistical analyses were corrected for multiple testing via the Benjamini and Hochberg (Benjamini & Hochberg, 1995) method, and all analyses conducted in R version 4.0.3 (R Development Core Team 4.2.1., 2022) for MacOS.

3. Results

3.1. Grades

Student performances did not differ significantly between the two cohorts in the exam question taught via lectures to both cohorts ("question lecture"; first cohort: n = 51, mean grade = BC; second cohort: n = 66, mean grade = B; Mann-Whitney U test, W = 1458.5, p = 1), for the exam question whose contents were taught with lectures to the first cohort, and via the concept maps to the second cohort ("question concept maps"; first cohort: n = 51, mean grade = B; second cohort: n = 66, mean grade = B; Mann-Whitney U test, W = 1610, p = 1), nor for overall exam performance (first cohort: n = 51, mean grade = BC; second cohort: n = 66, mean grade = B; Mann-Whitney U test, W = 1254.5, p = 0.1576693, Figure 2).

3.2. Student survey

The full survey data is attached as supplementary data to this study (Table S2, Supplementary Materials).

3.3. Student perception of learning success

According to the student survey, working with the concept map enabled most students to memorize the study topics (a sign of shallow learning approaches), but also to describe, explain and hypothesize about the topics, meaning a significant amount of students reported using deep learning approaches (seven exact binomial tests, all $n = 45$, $27 <$ number of successes < 42, all $p < 0.05$; Figure 3). More than 90 % of students felt like they had understood the topics covered by the concept maps, more than 70 % felt like they could memorize, describe or explain the topics, and more than 50 % felt like they could hypothesize about the topics, the deepest level of learning examined in this survey. Furthermore, more than 70 % of students reported that the maps gave them the chance to explore topics freely.

Neither teaching method, concept map, nor lecture, was significantly preferred by students (two exact binomial tests, both n = 44, 12 < number of successes < 15, both p = 1; Figure 3). All students that preferred the lecture and used the word "get" when asked the reason for their preference (Figure 4), used this phrase in the context of "getting information" (Table S2,

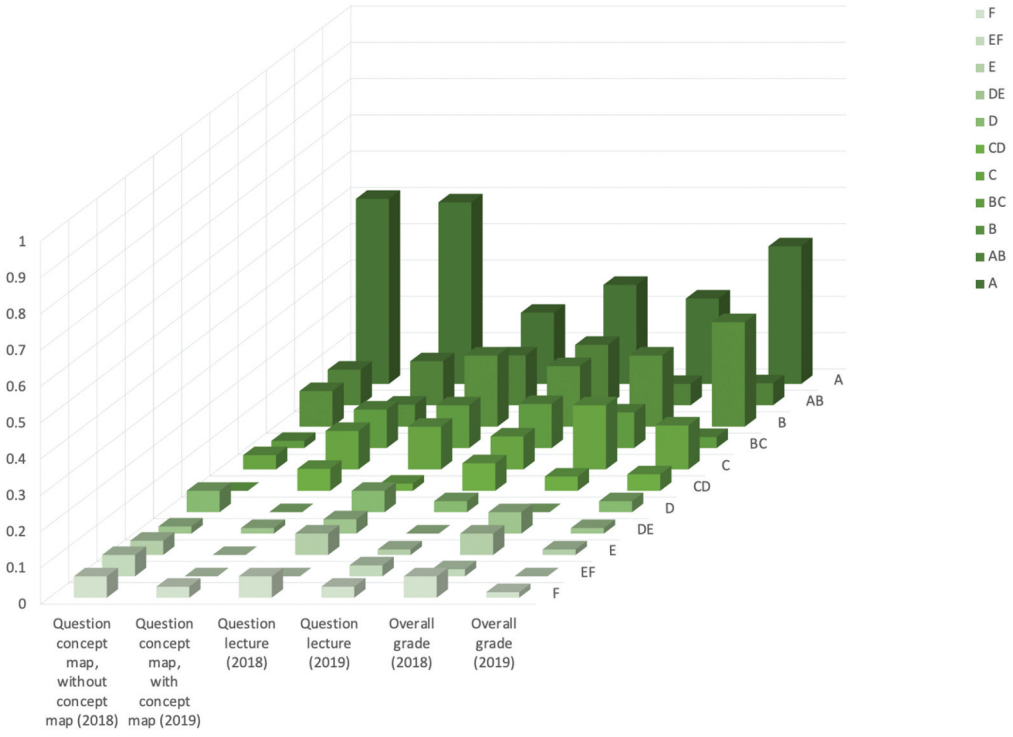

Figure 2. Final exam grades of first-year students joining biology and animal science bachelor programs as well as exchange students, in two consecutive years. In 2018, both question categories were taught via classical lectures. In 2019, one category was taught with topic-related concept maps, and the other via lectures. No significant changes were detected in student grades after the introduction of the concept map ($p > 0.05$).

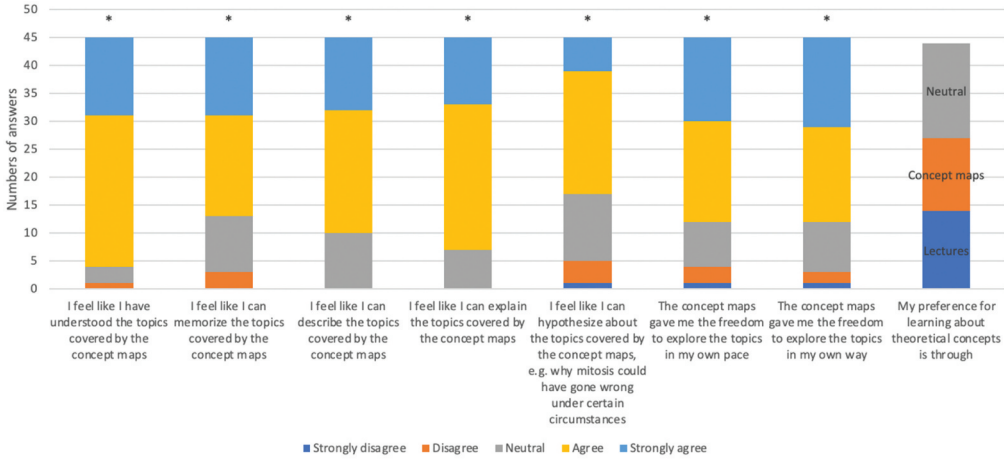

Figure 3. Answers to a student survey, examining perception of learning outcomes after working on two concept maps in the first year of a biology and an animal science programme, as well as an exchange students programme. Shown here are the survey questions related to perception of different levels of learning, as well as the acceptance of the teaching method by students. Asterisks indicate significantly more ($p < 0.05$) positive feedback ("Agree"/

Supplementary Materials). Other popular words were "easier" and "right" in cases of students preferring the lecture, for example as in "Easier to get the right information about the topics". For students preferring the concept map, word usage included "chance" and "study" as in *e.g.* "You get the chance to be creative and study it on your own", and also again "get". However, in contrast to students preferring the lectures, they used "get" in the context of "gaining freedom".

3.4. Loneliness

Students did not report a significant positive effect of group work on different aspects of loneliness (eight exact binomial tests, $43 < n < 46$, $5 <$ number of successes < 18, all $p = 1$, Figure 5).

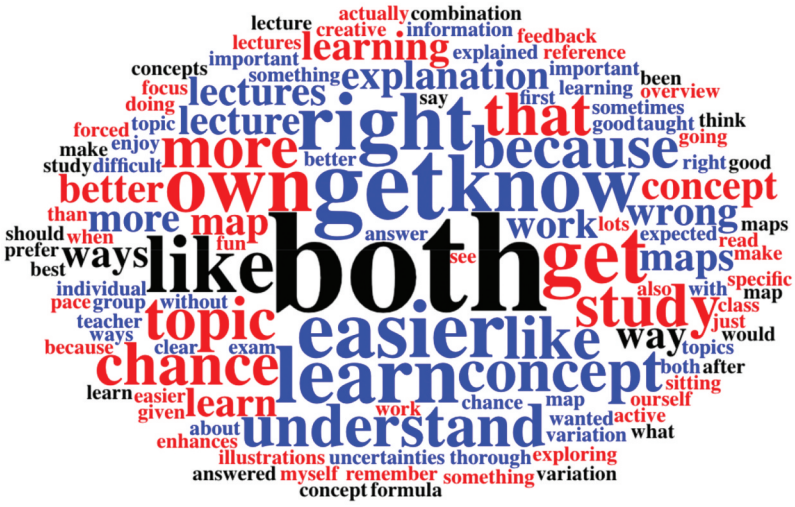

Figure 4. Word cloud based on answers to a student survey question: "Why did you prefer either the concept maps or lectures?", with answers representing students who preferred lectures in blue (*n* = 12), answers representing students who preferred concept maps in red (*n* = 11), and answers representing students that did not prefer either teaching method in black (*n* = 8). Participants were mostly non-native English speakers, therefore, phrasing might be misleading.

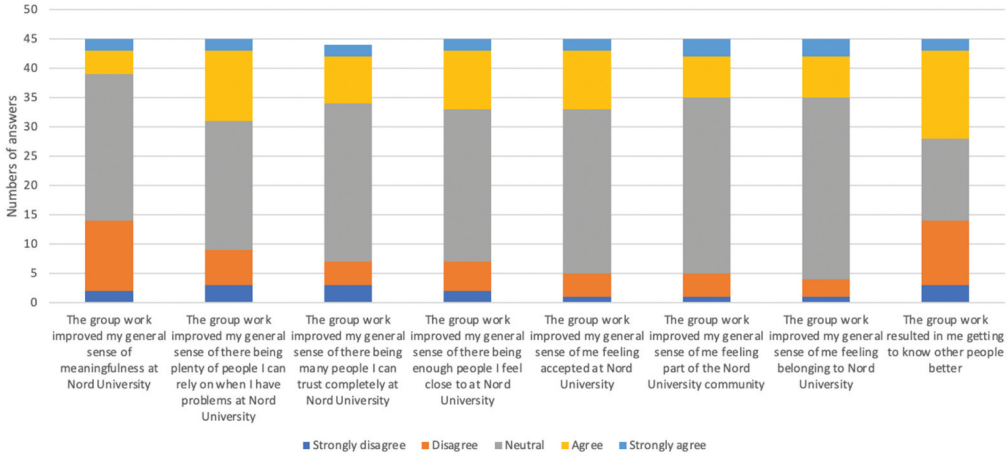

Figure 5. Student answers to a survey, examining their experience of working on two concept maps in the first year of a biology and an animal science programme, as well as an exchange students programme. The maps were filled out individually, followed by group work. Shown here are the survey questions related to the students' feeling of loneliness in response to the group work. No significant positive effects were detected (all $p > 0.05$).

4. Discussion

Active learning techniques have been shown to influence student performance positively in some cases (Deslauriers & Wieman, 2011; Deslauriers et al., 2019; Freeman et al., 2014). Here, we report that the implementation of two concept maps in a first-year bachelor course did not significantly impact student performance. However, most students reported learning success, if defined as deep learning such as being able to explain and hypothesize about a study topic, while student acceptance of the active learning method was equal to that of a traditional lecture approach.

Active learning approaches have become increasingly popular in higher education, and are acknowledged to be excellent approaches to enhance student learning (Deslauriers & Wieman, 2011; Freeman et al., 2014). In the present study students reported deep learning levels when studying autodidactically via concept maps, however, this was not tested against student responses after teaching via classical lectures. Furthermore, our concept map approach did not detectably alter student performance, although it has been shown that this approach can have a significant positive effect on grades and learning outcomes (Aliyari et al., 2019; Garwood et al., 2018; Jaafarpour et al., 2016). On the other hand, our study included only one student cohort per treatment. Student cohorts are known to differ strongly, therefore the concept maps might have had a stronger effect on other student cohorts. Active learning has been shown often to enhance learning, especially for low to mid-performing students; therefore weaker student cohorts may benefit more from the concept map (Weltman & Whiteside, 2010).

However, the concept maps did not negatively influence student performance, and therefore can be considered a valid alternative teaching method compared to classical lectures. Furthermore, the concept maps were broadly accepted as a learning tool among students in our study, an unusual case for active learning approaches. In general students are known to prefer learning via classical lectures, possibly due to feeling more secure with being taught by an authority (Finelli et al., 2018; Melovitz-Vasan et al., 2018). Accordingly, a considerable proportion of students that preferred the concept map in our study argued that it is easier to be taught the topics by a teacher, instead of possibly focussing on non-relevant topics, or interpreting certain topics incorrectly during self-study. Furthermore, one of the most used terms of students preferring lectures was the word "get" in the context of "getting information" passively from a teacher. However, overall students in our study did not disapprove of active learning, with neither concept map nor lecture being significantly preferred. The feedback of the teacher on concept maps might have enhanced the feeling of security amongst students, leading to reported wide acceptance of active learning. If such minor control by the teacher as used here can reassure students during self-study, its broader implementation might be a way to improve wider acceptance of active learning among students in the future. Furthermore, the feedback could benefit both students and teachers, providing information on the learning progress of their students.

The group discussions included in our study design may have contributed to increasing student confidence in having learned and understood the topics, by allowing them to compare and discuss their concept map with peers. In our approach group discussions had the additional goal of improving mental health. One third of students reported becoming better acquainted with their fellows through organized group work. However, conversely group discussions did not fulfil their main purpose of decreasing the feeling of loneliness among students, a matter of considerable concern in the study country (Knapstad et al., 2018). A possible cause might have been the low number of only two group work sessions combined with the fact the course was held during the second half of the first study year, which possibly resulted in a negligible impact on students' social circles. Increasing the number of group work sessions might show the intended benefits in the future, with students not only becoming better acquainted with their compatriots, but also connecting on a deeper level, and at the same time further improving their professional security during self-study.

5. Limitations of this study

The authors acknowledge that this study has several limitations, besides the ones already discussed. The data for student loneliness is derived from self-reports only, which are likely to be biased by social desirability. The same is true for the reports on students' self-perceived depth of learning levels achieved, and also for their reported acceptance of concept map teaching. The experimental setup, as well as the behaviour of teachers, will have made it obvious to students that their approval of concept maps, compared to the classical lecture approach, was a socially desired outcome. In addition, the authors would like to highlight that exam grades accumulated as one grade each for "question concept map" and "question lecture" were not tested for internal consistency reliability, due to limited data availability.

6. Conclusion and outlook

Taken together, the concept maps used here can be considered a valid alternative to classical lectures. Active learning applications can be expected to become more widespread in the future in higher education, as increasingly they are recognized to improve student performance. At the same time, student numbers are rising in many countries, adding to staff teaching loads. Active and self-responsible learning by students could help teachers cope with the increasing demands of teaching, while at the same time offering an opportunity to improve the well-being of students, by giving them the chance to conduct their studies in a free, self-reliant way.

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