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Cooperative learning goes online: teaching and learning intervention in a digital environment impacts psychosocial outcomes in biology students

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A R T I C L E I N F O

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A B S T R A C T

Identifying evidence-based teaching and learning strategies that can ease teacher challenges and mitigate student concerns in digital settings becomes increasingly important. In this intervention study we compared the effect of digital cooperative learning (CL) and digital lectures on a range of psychosocial outcomes, specifically students' sense of belonging, science confidence, perceived generic skills, and loneliness, among a Norwegian sample of undergraduate biology students ($n = 71$). Employing a one-group pretest/posttest quasi-experimental design with a double pretest and follow-up, we found that students' scores on psychosocial outcomes improved significantly following digital CL compared to digital lectures. Further, the effect sizes suggest that the effect of CL on psychosocial outcomes in digital settings is at least as substantial as in physical settings.

1. Introduction

The need for digital teaching and learning strategies that can lead to desirable student outcomes in higher education has received considerable attention, and the COVID-19 pandemic has only spurred this need (Damşa et al., 2015; European Commision, 2021; Henrie et al., 2015; Lillejord et al., 2018; Lashley et al., 2020a). Following imposed restrictions on social contact, teachers all over the world moved their courses from physical classrooms to online platforms almost overnight (Crawford et al., 2020). For many of the teachers this transition led to both frustration and difficulties in facilitating a digital learning environment (Houlden & Veletsianos, 2020; Mazur et al., 2021a; Watermeyer et al., 2021). The transition to digital learning was also challenging for students, who reported lack of social contact, increased loneliness, and difficulties in studying from home (Børve et al., 2021; Deng et al., 2021; Lederer et al., 2021; Phillips et al., 2022; Sivertsen, 2021; Tice et al., 2021; Werner et al., 2021). Even though it is difficult to determine whether these student concerns were mainly due to digital learning, or the restrictions of the pandemic in general, they deserve closer attention. Digital teaching may affect students differently than traditional in-person teaching. For example, the inherent distance embedded in digital teaching and the reported student concerns indicate that psychosocial outcomes are particularly vulnerable to a digital setting.

Despite these teacher and student challenges, initiatives to implement digital learning in higher education have only gained strength in the wake of the pandemic (European Commision, 2021). While specialized online courses have been offered for years,

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remote instruction is likely to remain part of the standard curricula in higher education (European Commision, 2021; Hodges et al., 2020). Thus, in this study we sought an evidence-based and student-centered teaching and learning strategy that could be implemented in a digital setting, effectively facilitate learning, and mitigate student psychosocial concerns, specifically students' sense of belonging, science confidence, perceived generic skills, and loneliness.

Previous studies from non-digital higher education settings show that active and cooperative learning (CL) methods enhance student learning and wellbeing more so than lectures (Deslauriers et al., 2019; Freeman et al., 2014; Loh & Ang, 2020). While these methods have traditionally been applied in physical classrooms, it is hypothesized that these findings may be transferable to a synchronous online context (Davidson, 2021). To test this hypothesis, we conducted an intervention study in a sample of undergraduate biology students (n = 71) in Norway, employing a one-group pretest/posttest quasi-experimental design with a double pretest and follow-up (Shadish et al., 2002). During the intervention, we implemented several evidence-based CL methods in a digital setting and explored if such methods were associated with any change in the students' psychosocial outcomes, i.e., students' expressed sense of belonging, science confidence, perceived generic skills, and loneliness compared to traditional digital lectures.

2. Cooperative learning (CL)

Cooperative learning (CL) was developed by Johnson and Johnson (1989), among others, and may be defined as: '...a highly structured form of group work' (Millis, 2010, p. 5) and '…the instructional use of small groups so that students work together to maximize their own and each other's learning' (Johnson et al., 1998, p. 14). According to Millis and Cottell (1998), key principles of CL in higher education include (i) positive interdependence, i.e., that the group members need to cooperate to complete the tasks, and have mutual gain and shared goals, and (ii) individual accountability, i.e., that each group member is accountable, thus preventing social loafing.

The principles of positive interdependence and individual accountability should underpin both CL group features and structures (Gillies, 2016; Millis & Cottell, 1998) and to achieve this, CL literature suggests, in compliance with the definition, that groups need to be highly structured (Gillies, 2003). Thus, groups should be relatively small, of three to five students, to avoid free-riding behaviour, allow less forthright students to participate, and more generally enhance learning (Kagan, 2021; Millis & Cottell, 1998). Also, groups should be formed by the teacher based on student characteristics such as academic ability, background, age, and gender, with the aim of creating diverse groups (Johnson et al., 1994; Kagan, 2021; Millis & Cottell, 1998). This will enforce mutual dependence, perspective taking, and case argumentation (Piaget, 1985), the knowledge and autonomy level of both low-ability and higher-ability students (Jacobs et al., 2006; Lou et al., 1996), and group discussion quality and group performance (Curşeu et al., 2018). Further, the use of CL structures helps the students to complete the assignment in alignment with the CL principles (Millis & Cottell, 1998). Because CL structures are content-free strategies (Kagan, 2021), they can be employed in any subject and on any educational level, including higher education. Key CL structures used in the present study are presented in Box 1 and 2.

2.1. CL outcomes

CL outcomes are traditionally divided into three categories (Johnson & Johnson, 2018): 1) efforts to achieve (e.g., academic motivation, persistence, productivity, and performance, 2) relationships (e.g., social skills, promoting each other's success, and forming academic and personal relationships), and 3) mental health (e.g., personal ego-strength, self-confidence, and autonomy), and there is a reciprocal relationship between these three categorical outcomes (Johnson & Johnson, 1989, p. 9). In higher education most CL studies have been related to the first of these three categories and in particular to higher student academic performance (Loh & Ang, 2020). The relationship between CL and academic performance is thoroughly established and the greatest impacts on students during the digital transformation induced by the pandemic have been psychosocial (Børve et al., 2021; Deng et al., 2021; Händel et al., 2020; Lederer et al., 2021; Phillips et al., 2022; Sivertsen, 2021). Therefore, this study has focused on student *affect* in relation to digital CL methods. Previous studies on CL in Science, Technology, Engineering, and Mathematics (STEM) higher education indicate that CL in physical learning environments may be positively associated with a range of psychosocial outcomes (Canelas et al., 2017; Espinosa et al., 2019; Furuto, 2013, 2017; Kocak, 2008; Pilcher et al., 2015; Rattanatumma & Puncreobutr, 2016; Rivera, 2013; Wilton et al., 2019; Yapici, 2016). However, to the best of our knowledge these studies are few, have been conducted in educational settings very different from ours, or have not explored CL methods in a fully digital setting. Thus, in this intervention study we implemented several CL methods digitally and examined the following psychosocial outcomes: students' expressed sense of belonging, science confidence, perceived generic skills, and loneliness.

To belong is regarded as a basic human need (Baumeister & Leary, 1995; Maslow, 1968) and **sense of belonging** is defined as our experience of being an integral part of our surrounding systems or environment (Hagerty et al., 1992, p. 173). One such system may be higher education; for example, previous research shows that sense of belonging seems to be particularly important for student retention in STEM higher education (Appleton et al., 2006; Rainey et al., 2018, 2019; Smith et al., 2013; Trujillo & Tanner, 2014). We fulfil our need to belong by engaging in meaningful interpersonal relationships and social interactions (Baumeister & Leary, 1995) and as a result, groups and group work facilitating student interaction in higher education may lead to increased sense of belonging. Thus, sense of belonging has been examined as one of many student outcomes of CL, including in undergraduate STEM education (Furuto, 2017; Wilton et al., 2019; Yapici, 2016), but never in a fully digital setting. Further, perceptions of belonging and opportunities to belong, among others, reinforce each other continuously in the development of belonging (Allen et al., 2021). Hence, universities should implement intentional, consistent, and systematic practices to become *places of belonging* (Murdock-Perriera et al., 2019), especially now as students' sense of belonging has decreased during the pandemic (Lederer et al., 2021; Sivertsen, 2021; Tice et al., 2021). In an attempt to increase and examine the students' sense of belonging in a digital setting, we include sense of belonging in the present study.

Science confidence is a malleable trait (Burns et al., 2016). In this study, we understand science confidence as a student's perception of their own abilities *to learn and complete* tasks specific to science, such as articulating a testable hypothesis, designing an experiment, or explaining scientific concepts to peers (Cotner et al., 2020b; Seymour et al., 2004). Thus, our understanding aligns with literature in the discipline-based educational research communities stating that science confidence appears closely related, but not identical to, *(science) self-efficacy* (Ainscough et al., 2016; Ballen et al., 2017a; Cotner et al., 2020b; Nissen & Shemwell, 2016; Rittmayer & Beier, 2008). Self-efficacy is the belief in one's capacity to organize and execute the courses of action required to manage prospective situations (Bandura, 1997) and consequently *scientific self-efficacy* may capture students' belief that they are capable enough to master scientific tasks and obtain successful results. Like science confidence, self-efficacy may also be considered malleable. In fact, Camfield et al., (2021) recently demonstrated how STEM students' efficacy beliefs were positively influenced by student-centered interventions during COVID-19 remote instruction. In previous undergraduate STEM education studies on CL interventions specifically, scientific self-efficacy has also improved (Espinosa et al., 2019; Furuto, 2013, 2017; Rivera, 2013). Thus, we consider it likely that task-specific science confidence may be a positive student outcome of CL. Generally, confidence and self-efficacy are positively associated with desirable student outcomes such as better performance and retention in a discipline (Ballen et al., 2017a; Rittmayer & Beier, 2008). These associations may be understood through the lens of social cognitive career theory (Bandura, 1986; Lent et al., 1994) - whereby a perceived reduced capacity, and possibly a consequent *lack of belonging*, in a discipline informs an individual's self-evaluation and sense of a future in that discipline (Stake & Mares, 2005; Wonch Hill et al., 2017). As student sense of belonging has decreased during the pandemic (Lederer et al., 2021; Sivertsen, 2021; Tice et al., 2021), we hypothesize that science confidence may be affected, too. Further, science confidence has, to the best of our knowledge, not been examined as one of the typical student outcomes of CL in science higher education - and certainly not in Norwegian higher education. Thus, the present study examines the students' expressed science confidence.

Generic skills are also known as "21st century skills", "life skills", and "transferable skills", (UN, 2015; UNICEF, 2021) and may be understood as holistic skills which operate across wide ranges of contexts (Taber, 2016, p. 226), and often predict success in life (Heckman & Kautz, 2012, p. 2). Such skills are developed through interaction with our surroundings and are important tools for lifelong learning (Bourn, 2018), highly desired by employers (Davey et al., 2018; Male et al., 2011), and believed essential to navigate in an unpredictable future. This broad understanding of generic or 21st century skills together with the focus on and measurement of the students' *perceived* generic skills, lay the foundation for categorizing generic skills as a psychosocial outcome in the present study. Generic skills (or 21st century skills) include a) ways of thinking: e.g., creativity, critical thinking, problem solving, and meta cognition, b) ways of working: e.g., collaboration and communication, c) tools for working: e.g., information and communication literacy, and d) living in the world: e.g., citizenship and life and career (Binkley et al., 2012, pp. 18-19). Generic skills seem to be developed through an integration of content knowledge and active learning methods, particularly group work (Ballantine & McCourt Larres, 2007; Kember et al., 2007; Smith & Bath, 2006; Tynjälä & Gijbels, 2012; Virtanen & Tynjälä, 2019; 2022) and as a result, improved generic skills may be one of the more prominent student outcomes of CL (Johnson & Johnson, 2016; Millis & Cottell, 1998). In previous studies in STEM higher education, the positive effect of CL on generic skills and/or perceived generic skills has been examined in both physical settings (Canelas et al., 2017; Pilcher et al., 2015; Rattanatumma & Puncreobutr, 2016) and digital settings (Lee et al., 2016; Parsazadeh et al., 2018). However, these studies are few and have never been conducted in a fully digital setting in STEM higher education similar to ours. Thus, we include perceived generic skills as one of our outcome measures.

Loneliness is a subjective feeling of distress due to deficiencies in an individual's social relationships (Peplau & Perlman, 1982, p. 3). Moving away from the safety of home and suddenly having to manage on their own, university students may be particularly vulnerable to loneliness (Cutrona, 1982; Stewart-Brown et al., 2000). Student loneliness is on the rise (Knapstad et al., 2018) and has increased substantially during the COVID-19 pandemic (Phillips et al., 2022; Sivertsen, 2021; Werner et al., 2021). Furthermore, loneliness among university students may cause health problems (Hayley et al., 2017; Richardson et al., 2017). To prevent and counteract loneliness, universities may facilitate initiatives (both within and beyond the classroom, physically and digitally) to decrease loneliness (Adriansen & Madsen, 2012), and increasing opportunities for social interaction is particularly promising (Hawkley & Cacioppo, 2010). CL is an example of an initiative that may offer such opportunities and previous research indicates that CL may lead to psychological health benefits (Johnson et al., 2014), including reducing feelings of loneliness in university populations (Kocak, 2008). In this study, we test if CL may also reduce students' self-reported loneliness in a digital setting.

3. Hypothesis and prediction

Increased digital components in standard university courses, and post-pandemic student concerns in higher education in Norway and elsewhere indicate a need to identify digital learning strategies which strengthen student outcomes. Cooperative learning (CL) offers a coherent and evidence-based framework for such methods but has not previously been systematically implemented or tested in a digital undergraduate STEM setting similar to ours. We capitalize on a rare opportunity offered by an undergraduate course in biology during the COVID-19 pandemic, where we implemented an experimental digital CL period into a course otherwise consisting of remote lectures and labs. Specifically, we consider the course in three parts, a lecture period, a cooperative learning experimental period, and a second lecture period, to address the following hypothesis and specific prediction:

Hypothesis 1. (H1): *Digital cooperative learning methods lead to beneficial changes in biology students' self-reported psychosocial outcomes compared to traditional digital lectures.*

Specifically, we predict that a digital cooperative learning intervention will increase the students' self-reported sense of belonging, science confidence, and perceived generic skills, and lead to a decrease in loneliness scores.

4. Methods

4.1. Participants

The participants in this intervention study all attended an undergraduate introductory biology course and thus made up a convenient sample. The course counted 86 students, but we only included the 71 students who participated in all four data collections throughout the semester, resulting in a response rate of 83%. This rate is high, especially given the amount of measurement time points (Yu et al., 2017). Participants included 39 females (55%) and 32 males (45%). Age was divided into three intervals: born in year 2000 or later (17%), born in year 1998 or 1999 (53%) and born in year 1997 or earlier (30%). 10% of the students stated that neither of their parents had higher education, 24% had one parent with higher education and 66% responded that both parents had higher education.

4.2. Procedure: Data collection

The intervention was conducted during the spring semester 2021 and all data used in this study were collected by means of four digital surveys conducted during that period. The content of the four surveys was identical but the framing differed from the first to the remaining surveys. As the first survey was administered in the first lecture of the semester, the students were asked to give their answers drawing on experience from similar large mandatory undergraduate biology courses in the *preceding semester* and for most students, in the same program. The three remaining surveys were administered at different time points and equally distributed throughout the semester; here, the students were asked to give their answers based on their experiences in the *preceding month* (Fig. 1). Each student was allowed 15 minutes to complete each of the four surveys. The data collection was digital, using SurveyXact by Rambøll (Rambøll, 2021) and the main researcher was available for questions throughout survey completion.

The data collection procedures followed the regulation of the General Data Protection Regulation (European Commision, 2022) and was approved by the Norwegian Centre for Research Data (Norwegian Centre for Research Data (NSD), 2021). Due to the psychological variable "loneliness" the Regional Committee for Medical and Health Research Ethics (Regional Committees for Medical and Health Research Ethics (REK), 2020) was also consulted to ensure that the data collection adhered to the health research ethics regulations. The participants were informed of the purpose of the study, that their participation was voluntary and that they could withdraw from the study at any time. Furthermore, they were informed that any personal data, specifically the student ID-number which we collected to trace the responses of each student, would be de-identified, treated confidentially, and deleted after the completion of the study.

4.3. Procedure: Study design

The intervention study was carried out in a large mandatory undergraduate biology course at a Norwegian university. It lasted one semester and included the following remote elements: five weeks of lectures, five weeks of cooperative learning (CL), a week of lab work, and an additional five weeks of lectures. The lectures took place on Zoom, with the CL sessions in Zoom break-out rooms. To carry out the intervention and measure possible changes in the students' psychosocial outcomes, we adopted a quasi-experimental design (Shadish et al., 2002). Quasi-experimental studies are particularly useful when randomization is not feasible due to natural criteria, e.g., class enrollment (Crano et al., 2015; Shadish et al., 2002). Given the fact that we lacked an equivalent control group, we used a one-group pretest/posttest design with a double pretest and follow-up. Using a double pretest and follow-up reduces the risk of errors due to student maturation and regression (Shadish et al., 2002) and a minimum of five weeks between every measurement reduces the risk of survey fatigue (Creswell, 2014). To illustrate the flow of the study, we refer to Figure 1.

This study – in addition to the double pre-test and follow-up measurements - adopted a range of design controls (Shadish et al., 2002) such as: a) Two long, uninterrupted, and consistently structured periods of lectures in order to establish a baseline and follow-up score, b) An equally long, uninterrupted, and consistently structured CL intervention period to allow comparison across the periods and their relative impacts, c) Uniform instruction and training of the teaching assistants (TAs) to control for between-group differences (Cox, 2015), d) Mandatory student attendance to avoid missing by design (Jeno et al., 2017), e) Allocating the digital lectures and the digital CL group seminars to a fixed time of day to remove environmental differences, f) Incorporating the same kinds of topics throughout both the lecture and the intervention period to avoid any between-interest effects (Jeno et al., 2017) and g) Not revealing our hypotheses to the teachers or the TAs to avoid an impact on their interactions with the students.

Fig. 1. Overview of measurement time points (blue) and digital teaching and learning (orange = lectures, green = cooperative learning (CL) intervention, grey = lab exercises) during the semester.

Box 1
Implemented CL structure: Group contract.

A group contract provides guidelines for group work and group tasks with the purpose of establishing common expectations and tools to secure workflow, develop constructive communication, and manage potential conflicts (Oakley et al., 2004). Here, we share specific guidelines from our intervention.

Group contract

Name of group:____

A group contract may ensure a positive work flow, harmony, and autonomy in group work. This group contract consists of two parts:

Part 1: An overview of fixed contractual group tasks
Part 2: A list of points to consider in your group work

Part 1:

Week	Individual preparations	Group tasks	Responsibility
9	For the third group zoom: Read text, study figures and answer the question about life cycle in general.	In the third group zoom: - Discuss life cycle in general - Agree on and distribute responsibility (expertise knowledge) for the life cycle of the following species: frog, bird, sea urchin and mouse - E-mail course responsible with an overview of the distribution of species (who becomes expert in what). Deadline: - Agree on time and convene for the fourth group zoom	Name: Name:
	For the fourth scheduled group zoom: Become an expert in "your" species and note down key content	In the fourth scheduled group zoom: - In expert groups: Compare and discuss your expert notes and decide on a presentation strategy - In home groups: Present «your» species and compare and discuss the life cycle of the four species. - Make a short joint presentation and upload it to the group site	Name:

Part 2:
Discuss and agree on the points you want to guide your group work. Write down and sign.

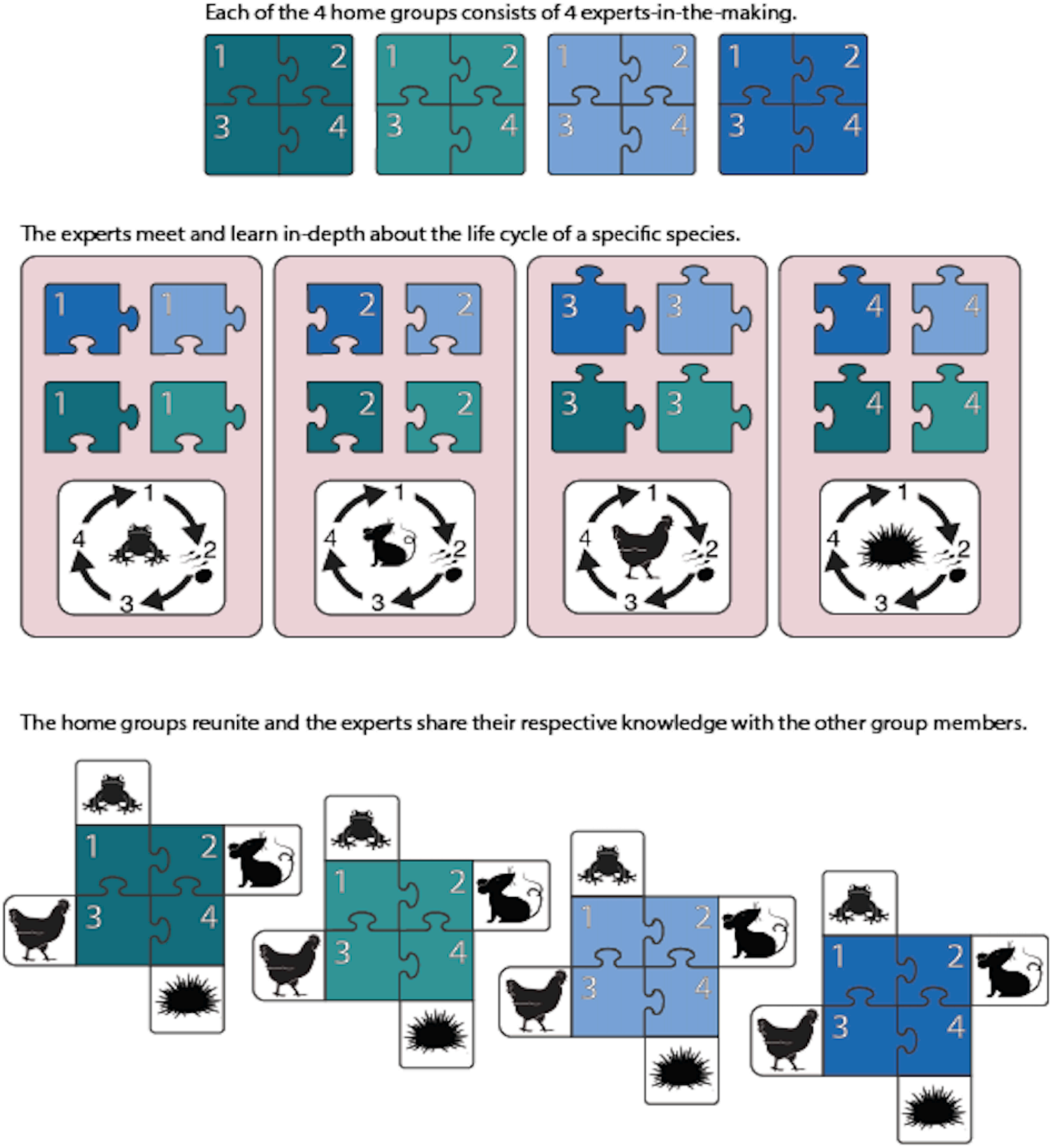
- Decisions. How do we make good and fair decisions in our group?
- Disagreement. How do we deal with disagreement?
- Contact. Where and when can we reach each other?
- Participation. How do we make sure that everyone participates on equal terms?
- ETC.

4.4. Procedure: The cooperative learning intervention

Cooperative learning (CL) methods implemented in the intervention period followed CL principles (Johnson et al., 1998), in particular positive interdependence and individual accountability (Millis & Cottell, 1998), and previous research on CL interventions in STEM higher education (Møgelvang & Nyléhn, 2022a). First, we included cooperation as a learning objective in the course description to be able to motivate the intervention and its assessment (Cheruvelil et al., 2020). Second, we formed 20 heterogeneous "home groups" of four students and two home groups of three students based on gender, age, and study program (Millis & Cottell, 1998). During the five-week CL intervention, the student home groups met twice a week: once in group Zooms initiated and conducted by the groups themselves and once in course-scheduled group breakout rooms. Each meeting lasted one to two hours. Third, we asked the groups to draw up group contracts as such contracts are associated with more positive student attitudes and higher student contribution within the groups (Aakre & Mørkve, 2021; Oakley et al., 2004). To ensure both an overview of the planned group work and ownership of the contract, the contracts consisted of two parts: (i) A table displaying scheduled individual and group tasks and (ii) A list of points for the group to consider ensuring mutual responsibilities and expectations. For the sake of reproducibility, we have included an excerpt of the group contract (Box 1). Fourth, we implemented "jigsaw" as the key CL structure throughout the intervention period. In previous research, jigsaw in undergraduate STEM education is linked to academic success, (perceived) generic skills,

Box 2
Implemented CL structure: Jigsaw.

Jigsaw: each group member takes responsibility for learning a specific part (piece) of a complex whole (jigsaw) and teaching it to the rest of the group. This way the group cooperates to put all the pieces of the jigsaw together (Millis & Cottell, 1998). Here, we share a specific jigsaw example from our intervention.



and positive student attitudes (Daniel, 2016; Pilcher et al., 2015; Yimer & Feza, 2020). One of the jigsaws in our study was related to the learning of academic writing (introduction, methods, results, and discussion) and the other jigsaw was related to the learning of life cycles in different species (mouse, frog, bird, and sea urchin), see example in Box 2. In both jigsaws, the groups divided the four expert responsibilities (puzzle pieces) between them, met in expert groups (in pre-set breakout rooms) before teaching it to their home group (in other pre-set breakout rooms). In line with the focus on structure, all the activities in the course-scheduled group discussions were subject to time and task management by the instructor and TAs using different call and chat functions in Zoom breakout rooms. For

Table 1
Descriptive statistics for the study variables (range 1-5) at all four time points (T1-T4).

	M	SD	Skw.	Kurt.	α
Sense of belonging, T1	3.99	0.63	0.04	-1.03	.90
Sense of belonging, T2	3.82	0.72	0.03	-1.15	.93
Sense of belonging, T3	4.09	0.65	-0.29	-1.03	.91
Sense of belonging, T4	3.95	0.72	-0.24	-1.01	.93
Science confidence, T1	4.03	0.54	0.04	-0.39	.92
Science confidence, T2	3.56	0.80	-0.99	1.80	.96
Science confidence, T3	3.86	0.62	-0.80	1.27	.94
Science confidence, T4	3.75	0.79	-0.95	1.50	.97
Perceived generic skills, T1	4.13	0.63	-0.18	-0.86	.90
Perceived generic skills, T2	3.50	0.89	-0.87	1.24	.93
Perceived generic skills, T3	3.91	0.90	-0.89	0.76	.93
Perceived generic skills, T4	3.80	0.86	-0.47	-0.08	.93
Loneliness, T1	2.51	0.84	0.17	-0.31	.76
Loneliness, T2	2.56	0.94	0.15	-0.62	.80
Loneliness, T3	2.34	0.93	0.26	-0.75	.86
Loneliness, T4	2.39	1.02	0.55	-0.40	.86

each jigsaw, each home group made a short presentation summarizing their findings and the learning outcomes were synthesized in academic reports. To promote individual accountability, each group member handed in their own report to be assessed individually. Finally, the student groups were allocated their own group site on the university's digital learning platform where they could keep in touch and share resources.

4.5. *Measures*

To measure the students' self-reported sense of belonging, science confidence, perceived generic skills, and loneliness, the present study employed validated scales capturing each of the latent variables. All scales have previously been employed both in international and Norwegian studies, and we used available translations and documentation as detailed below.

4.5.1. *Sense of belonging*

To measure the students' sense of belonging in the course, we used the *Psychological Sense of School Membership* (PSSM) by

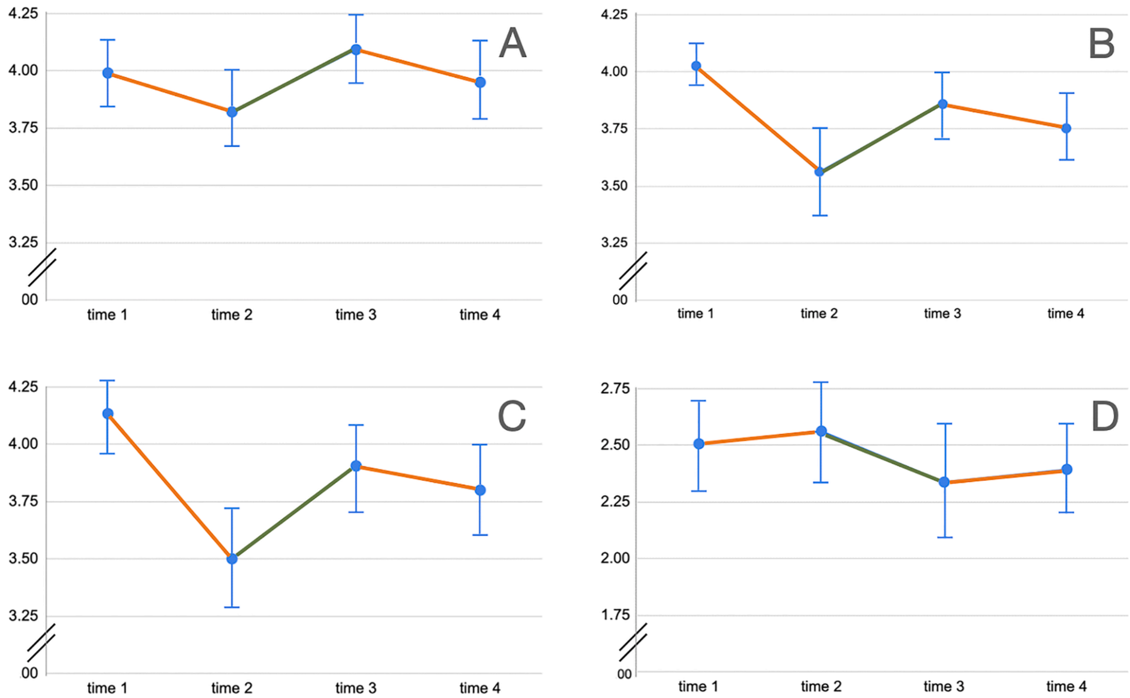


Fig. 2. Close-up four-panel figure illustrating the change in students' expressed sense of belonging (A), science confidence (B), perceived generic skills (C), and loneliness (D) including confidence intervals measured at four time points using Likert scales from 1 (strongly disagree/never) to 5 (strongly agree/very often).

Goodenow (1993). In recent higher education studies, the PSSM seems to be multidimensional resulting in three different factors equivalent to a sense of social belonging (peer-related), a sense of academic belonging (tutor-related), and a general sense of belonging with reliability estimates ranging from low .70s to .90 (Alkan, 2016; Freeman et al., 2007; Møgelvang & Nyléhn, 2022b). The original scale consists of 18 statements such as "Other students in this university/school/course take my opinions seriously", "The teachers here respect me" and "I can really be myself at this university/school/course" which are measured on a 5-point Likert scale from *strongly disagree* (1) to *strongly agree* (5). However, due to poor fit in a previous Norwegian study (Møgelvang & Nyléhn, 2022b), we removed two of the items.

4.5.2. Science Confidence

For measuring the students' science confidence, we used a scale of items adapted from previous studies investigating students' science confidence (Lopatto, 2004; Seymour et al., 2004). The scale used in the present study has previously been employed and tested for reliability for US (Walker et al., 2008) and Norwegian biology students (Cotner et al., 2020b). The scale has 13 items which are measured on a five-point Likert-scale ranging from *strongly disagree* (1) to *strongly agree* (5) as response alternatives to items such as: I am confident I can… "Discuss scientific concepts with my friends or family" and "Interpret tables and graphs".

4.5.3. Perceived generic skills

The students' perceptions of their generic skills were measured using the subscale "Generic skills" in the *Course Experience Questionnaire* (CEQ) (Ramsden, 1991). The subscale comprises six statements such as "The course sharpened my analytical skills" which are measured using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In previous international publications, the reliability of the CEQ "Generic skills" subscale has been acceptable, ranging from the high .60s to high .70s (Byrne & Flood, 2003; Jansen et al., 2013) and from .77 to .81 in Norwegian studies (Espeland & Indrehus, 2003; Møgelvang & Nyléhn, 2022b).

4.5.4. Course loneliness

We measured loneliness using the short "Three-Item Loneliness Scale" (TILS) developed by Hughes et al., and Cacioppo (2004). This instrument consists of three items: "How often do you feel that you lack companionship?", "How often do you feel left out?", and "How often do you feel isolated from others?" These three items are measured on a 5-point Likert scale spanning from *never* (1) to *very often* (5). In previous research among adults, the TILS has shown acceptable reliability (α = .72 in Hughes et al. (2004) and α = .81 in Matthews-Ewald and Zullig (2013)). The TILS has also been employed in a large Norwegian study (Knapstad et al., 2018).

4.6. Statistical analyses

Only participants who completed all four surveys were included in our analyses. To address the research hypothesis and prediction, we conducted a range of *confirmatory* analyses using IBM SPSS Statistics 27 (IBM, 2021). First, we assessed factor structure, normal distribution, and internal consistency by running factor analyses, descriptive analyses, and reliability analyses measured with Cronbach's alpha (Cronbach, 1951). Second, to explore whether the students' scores on the outcome variables changed throughout the semester, we employed one-way repeated measures ANOVA, used Wilks' Lambda to assess significance, and adjusted for multiple comparisons through Bonferroni correction (Field, 2018). Effect sizes were measured in Partial Eta squared, which may be considered small (η_p^2 >.01 to .05), moderate (η_p^2 > .06 to .13), or strong (η_p^2 >.14) in magnitude (Cohen, 2013). As previous research shows that psychosocial outcomes can vary meaningfully by gender and generation in college (Abdul Karim et al., 2012; Ballen et al., 2017b; Hoffman et al., 2002; Master et al., 2016; Sæthre, 2014; Sahil et al., 2020; Salehi et al., 2019; Salehi et al., 2021b; Sivertsen, 2021; Thomas, 2012; Tinto, 1975, 1993) we also conducted *exploratory* analyses. Specifically, we ran Independent-samples t-tests and One-way between-groups ANOVA with Tukey post-hoc tests to detect whether our outcomes varied by student gender and generation in college.

5. Results

All variables met assumptions of normal distribution (Field, 2009) and acceptable reliability (Cronbach, 1951) at all four measurement time points (Table 1).

Through one-way repeated measures ANOVA, we found that coming into the course, the students scored relatively high (around 4.0 on the Likert scale) on expected sense of belonging, scientific confidence, and perceived generic skills, and relatively low on loneliness (2.5) (Fig. 2, time point 1). After five weeks of digital lectures, student's self-reported sense of belonging (-.17 [95% CI, -.30 to -.04] $p< .05$), science confidence (-.46 [95% CI, -.67 to -.25] $p< .05$), and especially perceived generic skills (-.63 [95% CI, -.92 to -.35] $p< .05$) had decreased significantly (values given are mean [CI]) (Fig. 2, time point 2). Loneliness did not change. After the next 5 weeks, during which students were engaged in the cooperative learning (CL) module, these trends were reversed, as sense of belonging (.27 [95% CI, .14 to .41] $p< .05$), science confidence (.30 [95% CI, .08 to .51] $p< .05$), and particularly perceived generic skills (.41 [95% CI, .14 to .67] $p< .05$), were significantly increased, and loneliness (-.23 [95% CI, -.42 to -.03] $p< .05$) significantly decreased (Fig. 2, time point 3). After the last 5 weeks of another series of digital lectures only sense of belonging (-.14 [95% CI, -.26 to -.02] $p< .05$) was significantly decreased. Science confidence and perceived generic skills did not change significantly and neither did loneliness (Fig. 2, time point 4). Further, students reported higher scores on sense of belonging and lower scores on loneliness after the intervention (time point 3) than they did coming into the course (time point 1). Science confidence and perceived generic skills, on the other hand, did not reach the levels from time point 1. None of the differences in scores between time point 1 and time point 3 were statistically significant. Taken together, all outcome variables changed over time, with large effect sizes for sense of belonging ($\eta_p^2 =$ .34), science confidence ($\eta_p^2 = .34$), and perceived generic skills ($\eta_p^2 = .44$), and a more moderate effect for loneliness ($\eta_p^2 = .13$) (Fig. 2, Appendix A).

Except for a significant difference between females and males on perceived generic skills coming into the course (time point 1), we found no statistically significant differences in mean scores when running exploratory analyses, based on either gender or generation in college, on any of the measured outcomes (Appendix B).

6. Discussion

6.1. Main findings

The purpose of this quasi-experimental study was to implement digital cooperative learning (CL) methods and explore if such methods were associated with any change in the students' psychosocial outcomes compared to digital lectures. The students' scores on all psychosocial outcomes changed positively and significantly after five weeks of digital CL compared to the five weeks of digital lectures preceding the CL intervention. In short, the CL intervention led to the students reporting increased sense of belonging, science confidence, and perceived generic skills, and decreased loneliness in comparison to traditional digital lectures. These positive changes cannot be explained by mere development over time. The four time points of our study design reveal that the downward trend following the first period of digital lectures was reversed during the CL intervention and then stopped or even reversed again when the CL methods were replaced by the second period of digital lectures. Consequently, the positive changes in the students' reported psychosocial outcomes seem to result from the implemented CL methods. In other words, if students' psychosocial outcomes in digital STEM higher education matter, the type of digital strategies we implement in our teaching should also matter. Our study indicates that digital lectures are not only unsuited for a positive development of students' sense of belonging, science confidence, perceived generic skills, and loneliness – rather, digital lectures seem to impair these psychosocial outcomes. Taken together, these psychosocial outcomes are nourished by collaborative and student-centered teaching strategies such as CL, not lectures, and our study demonstrates this, for the first time, in a digital learning environment. To the best of our knowledge all previous research on the effect of CL on psychosocial outcomes in STEM higher education, except for a few studies on the effect of online CL on select generic skills (Lee et al., 2016; Parsazadeh et al., 2018), has been conducted in a physical setting (Canelas et al., 2017; Espinosa et al., 2019; Furuto, 2013, 2017; Kocak, 2008; Pilcher et al., 2015; Rattanatumma & Puncreobutr, 2016; Rivera, 2013; Wilton et al., 2019; Yapici, 2016). Our results indicate that the general findings of these studies could be transferable to a digital setting.

6.2. Findings in light of previous research

When comparing our findings on the relationship between CL and psychosocial outcomes in a digital setting to previous research on the equivalent relationships in physical settings, we identify several correspondences, but also novelties, particularly regarding effect sizes. Like our study, previous CL intervention studies targeting sense of belonging showed a significant increase in sense of belonging following enhanced structure (Wilton et al., 2019) and various CL methods (Yapici, 2016). Both the influence (r = .30 to .49) of enhanced structure and the effect ($d = 0.5$ to 0.8) (own calculations) of CL methods on sense of belonging were moderate in magnitude (Cohen, 2013). In comparison, our study identified a very large effect size ($\eta_p^2 = .34$). Large effect sizes measured in eta squared or partial eta squared equal ($\eta^2_{(p)} >.14$). A study on the effect of CL on loneliness concluded that CL heterogenous groups and CL structures led to a significant decrease in loneliness compared to traditional teaching (Kocak, 2008), with an effect of ($\eta^2 = .06$). In our study, the effect was ($\eta_p^2 = .13$). According to Cohen (2013), both may be considered moderate ($\eta^2_{(p)} = .06$ to .13), but they figure in each end of the range. Our study is the first from STEM higher education in which CL has been specifically associated with science confidence. Previous research exists, however, on the relationship between CL and different types of science self-efficacy (Furuto, 2017; Rivera, 2013), which may resemble science confidence. These studies found significant increases in student self-efficacy following CL interventions employing heterogenous grouping, roles, and jigsaws compared to traditional teaching. Our calculations of the data in these studies show that the effect sizes varied from moderate ($d = 0.5$ to 0.8) (Rivera, 2013) to very large ($d > 0.8$) (Furuto, 2017) while in our study scientific confidence changed over time with a very large effect size ($\eta_p^2 = .34$). In the case of perceived generic skills, it is hypothesized that the inherent group and task structures of CL may stimulate the development of a range of generic skills (Millis & Cottell, 1998). A previous study from a physical setting did, like our study, find significant increases and very large effect sizes ($d > 0.8$) (Cohen, 2013) in a range of perceived generic skills following a CL intervention versus traditional lectures (Canelas et al., 2017). Likewise, a qualitative study replacing recipe-based lab teaching by jigsaw methods found a substantial increase in the students' (perceived) metacognitive skills (Pilcher et al., 2015). Contrary to relationships between CL and sense of belonging, loneliness, and self-efficacy, we did identify a few studies on the effects of online CL on generic skills in higher STEM education. These were conducted in settings very different from ours, but our study from a digital setting in a Norwegian higher biology sample supports their findings. One of these studies showed that the effect sizes of CL on information evaluation skills (Parsazadeh et al., 2018) were very large ($d >$ 0.8) (Cohen, 2013) and the other that CL leads to significantly increased critical thinking skills development (Lee et al., 2016).

We contribute to the understanding of CL impacts by supporting the findings of previous research on the effect of CL on several psychosocial outcomes compared to lectures, albeit in a *digital learning environment*. Our effect size for loneliness was in the upper range of moderate and the rest all very large in magnitude – which are equal to and in some instances even stronger than the effect sizes of previous research on CL in physical settings. Thus, our study suggests that the effect of CL on psychosocial outcomes in digital settings is *at least as* substantial as it is in physical settings. Taken together with the drastic decrease in sense of belonging, science confidence, perceived generic skills, and the increase in loneliness after the first period of digital lectures, we argue that psychosocial outcomes may in fact be particularly vulnerable to traditional teacher-centered instruction in a digital setting. If that is the case, it is an additional indication that teachers need to carefully consider how to teach digitally, and, encouragingly, that in a digital setting the added value of student-centered learning methods, exemplified by CL, may exceed those in physical settings.

6.3. Findings in light of theory

The drastic and positive change in the students' self-reported psychosocial outcomes during the digital cooperative learning (CL) intervention may indicate that digital CL provides many of the conditions theorized to improve student affect. In the case of science confidence, it is plausible that the CL group zooms provided the necessary experiences, e.g., interaction, working with specific scientific tasks, and immediate feedback to inform the students' positive self-evaluation and sense of a future in biology (Bandura, 1986; Lent et al., 1994). During the CL intervention the students worked cooperatively to solve biology tasks by means of jigsaw structures, thus integrating the two conditions hypothesized as needed to develop generic skills: content knowledge and active group work (Ballantine & McCourt Larres, 2007; Kember et al., 2007; Smith & Bath, 2006; Tynjälä & Gijbels, 2012; Virtanen & Tynjälä, 2019, 2022). Further, initiatives to increase students' inclusion and wellbeing (Adriansen & Madsen, 2012) through interaction and meaningful relationships (Baumeister & Leary, 1995) may be effective means to reducing loneliness and increasing sense of belonging. In our study, the students were given many opportunities to interact and experience meaningful relationships through highly structured, small, heterogeneous, and fixed CL groups with shared goals during the CL intervention (Gillies, 2003; Johnson et al., 1994; Kagan, 2021; Millis & Cottell, 1998). In fact, it should be noted that sense of belonging and loneliness, as the only of the measured variables, improved not only in comparison to the first period of lectures (time point 2), but also to time point 1 (Fig. 2). Time point 1 was when the students stated their expected sense of belonging and loneliness throughout the course based on experiences from similar courses the preceding semester. Hypothetically, the improvement in sense of belonging and loneliness measured after the CL intervention compared to both time point 2 (highly significant) and time point 1 (not significant), could be influenced by the types of student groups. Belonging to highly structured, small, heterogeneous, and fixed groups (Gillies, 2003; Johnson et al., 1994; Kagan, 2021; Millis & Cottell, 1998) may to a larger degree, than other types of groups, build up the necessary personal safety to interact and promote inclusion (Adriansen & Madsen, 2012; Baumeister & Leary, 1995), particularly in a digital setting where the threshold to initiate dialog seems higher than in a physical setting.

Theory may also help us understand why the positive developments in all psychosocial outcomes stopped or even reversed after the second period of lectures, and particularly why sense of belonging decreased significantly anew. Perceptions of belonging and opportunities to belong reinforce and affect one another continuously in the development of belonging (Allen et al., 2021), making consistent and systematic inclusion practices in higher education both important and required to secure the continuous sense of belonging among the students (Murdock-Perriera et al., 2019). The systematic practice to include all the students through the CL intervention disappeared when the second period of lectures began. Thus, the interaction needed to fulfil the need to belong also disappeared, and the students no longer experienced the same opportunities to belong. In a digital setting it is not just a matter of catching up with your group members in the break. The natural meeting place is simply not present, meaning that the importance of intended and systematic university practices to include all students become even more warranted in digital settings. The other psychosocial outcomes were more consistent when compared to sense of belonging. This may be related to science confidence being a malleable trait (Burns et al., 2016), while generic skills have been explained in terms of life-long learning (Bourn, 2018). Also, interventions offering targeted opportunities for social interaction seem to be successful in reducing loneliness over time (Hawkley & Cacioppo, 2010). All in all, the fact that none of the measured variables, except for sense of belonging, changed significantly in the second period of digital lectures may mean that there can be a lot to be gained from implementing periods of CL methods in digital settings.

7. Limitations and strengths

There are some limitations to our study. The design is quasi-experimental and lacks the advantages provided by randomization, and a control group could have strengthened the causal claims (Shadish et al., 2002). Self-reported measures, with their inherent biases, might also pose a limitation to the study (Czaja & Blair, 2005). Further, our conflation of the terms "science confidence" and "(science) self-efficacy" may be considered a limitation since the terms may not be as closely linked as the discipline-based educational research community seem to suggest. To counter any confusion and to promote transparency on this potential issue, we have included an overview (Appendix C) of how we measure science confidence (and all the other constructs) in the present study. The intervention was conducted in the spring 2021, i.e., in the middle of the COVID-19 pandemic when higher education in Norway was subjected to severe restrictions and the Norwegian population showed increasing signs of de-motivation and frustration with the seemingly endless situation. This backdrop may have influenced the answers of the students. Perhaps they would not have felt that discouraged from digital lectures nor that positive towards cooperative learning (CL) methods under different circumstances. Even so, we employed many design controls to strengthen causal claims (Shadish et al., 2002). These design controls and in particular the use of a double pre-test and a follow-up indicated a real and substantial difference in the students' psychosocial outcomes following the implemented digital CL methods compared to digital lectures. Further, a repeated measures design enables us to detect within-person change over time and has high statistical power (Guo et al., 2013, p. 100) and the effect sizes of the intervention were all very large, except for loneliness which was in the upper range of moderate. Thus, it is reasonable to infer that the changes in student scores in our sample are linked to the CL intervention rather than to confounding variables (Shadish et al., 2002). Also, the study adds new and valuable knowledge on a sample, i.e., Norwegian undergraduate biology students, and topic, i.e., digital CL methods, not previously researched. With digital teaching and learning on the rise, the knowledge gained from the digital nature of the study is especially valuable.

Our ability to extrapolate these findings to a larger higher-education community is limited. Our target population - Norwegian biology students - is relatively homogeneous, being composed primarily of continuing-generation, White, Norwegian-educated students, and may not be representative of populations elsewhere. Here we analyzed two aspects of diversity, i.e., gender and generation in college, and we did not detect any variability in response to the intervention. We cannot say for sure how students from, e.g., underrepresented racial or ethnic minorities might have responded to the intervention, but we hypothesize, based on similar studies (Binning et al., 2020; Hammarlund et al., 2022c) that the positive effects might have been even *greater* for these students. For example, a US-based study in introductory chemistry, (Hammarlund, 2022c) shows that a sense-of-belonging intervention positively impacted underrepresented minority students, but it did not differentially affect the performance of women or first-generation college students. We note further that the field of psychosocial classroom interventions is beset by a “replication crisis,” driven largely by studies conducted in one classroom, in one subject, in one geographic area - often the United States (Camerer et al., 2018; Open Science Collaboration, 2015). Few studies have investigated similar interventions in Norway, and none, to our knowledge, have explored the impacts of CL in a digital learning environment. Thus, our study population makes this work a valuable contribution to the growing field.

Finally, the addition of qualitative approaches would have added layers of understanding. For instance, interviews with students could have allowed us to better understand *which* features of CL best activated the positive outcomes and perhaps brought us closer to a more elaborate understanding of the benefits of CL. Thus, future studies will be strengthened by the incorporation of qualitative elements in the study design.

8. Conclusion

Taken together, our study adds new and valuable knowledge about digital teaching and learning in higher education. First, it underlines the differences between two digital teaching strategies in relation to psychosocial outcomes among students in higher education – and concludes that the positive effect of digital cooperative learning (CL) on psychosocial outcomes compared to digital lectures is substantial. Second, the findings suggest that psychosocial outcomes may be particularly vulnerable in a digital setting, making it even more important for instructors to pursue teaching strategies favoring such outcomes. Third, the effect sizes of the digital CL methods implemented in the study on psychosocial outcomes among the students were at least as strong as the effect sizes in previous studies on physical CL interventions (Canelas et al., 2017; Furuto, 2017; Kocak, 2008; Pilcher et al., 2015; Rattanatumma & Puncreobutr, 2016; Wilton et al., 2019; Yapici, 2016). This suggests not only that CL methods from physical settings may be transferable to digital settings, but also that the effect of CL in digital settings may be even greater than in physical settings. Fourth, digital settings do not offer spontaneous and informal meeting places for the students, making it even more important that higher education institutions implement systematic digital inclusion practices in all courses for all students. Our findings are in alignment with theory in the field of CL, sense of belonging, scientific confidence, generic skills, and loneliness.

In sum, teachers developing digital courses should take care to include student-centered approaches in their courses. Our findings suggest the positive impacts of this engagement can be meaningful and far-reaching, and we urge our colleagues in higher education to seek and implement digital strategies —such as digital CL—that promote student well-being.

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Declaration of Competing Interest

None.

Appendix A

Table A.1

Table A.1
Means, standard deviations, and one-way repeated measures ANOVA statistics for the study variables.

Variable	*M*	*SD*	*F*(3, 68)	*p*	η_p^2
Sense of belonging			11.87	<.001	.34
Time 1	3.99	0.63			
Time 2	3.82	0.72			
Time 3	4.09	0.65			
Time 4	3.95	0.72			
Scientific confidence			11.55	<.001	.34
Time 1	4.03	0.54			
Time 2	3.56	0.80			
Time 3	3.86	0.62			
Time 4	3.75	0.79			
Generic skills			17.99	<.001	.44
Time 1	4.13	0.63			
Time 2	3.50	0.89			
Time 3	3.91	0.90			
Time 4	3.80	0.86			
Loneliness			3.24	.028	.13
Time 1	2.51	0.84			
Time 2	2.56	0.94			
Time 3	2.34	0.93			
Time 4	2.39	1.02			

Table B.1
Means, standard deviations, and independent-samples T-tests for the study variables

Variables	Females		Males				
	M	*SD*	*M*	*SD*	*t*(69)	*p*	*d*
Sense of belonging							
Time 1	4.12	0.66	3.83	0.56	-1.95	.056	.46
Time 2	3.92	0.73	3.70	0.68	-1.32	.192	.31
Time 3	4.17	0.68	3.99	0.60	-1.17	.244	.28
Time 4	4.09	0.70	3.79	0.72	-1.76	.082	.42
Science confidence							
Time 1	4.11	0.46	3.93	0.61	-1.40	.165	.34
Time 2	3.54	0.85	3.60	0.74	0.31	.757	.07
Time 3	3.86	0.67	3.86	0.56	0.02	.986	.00
Time 4	3.79	0.77	3.71	0.83	-0.42	.676	.10
Generic skills							
Time 1	4.34	0.62	3.88	0.55	-3.27	.002	.78
Time 2	3.49	0.89	3.51	0.89	0.09	.929	.02
Time 3	3.96	0.91	3.84	0.89	-0.57	.569	.14
Time 4	3.94	0.86	3.64	0.86	-1.47	.146	.35
Loneliness							
Time 1	2.62	0.73	2.38	0.96	-1.20	.235	.29
Time 2	2.62	0.84	2.49	1.05	-0.60	.552	.14
Time 3	2.50	0.83	2.15	1.02	-1.59	.115	.38
Time 4	2.39	1.01	2.40	1.04	0.01	.991	.00

Note. Females (n=39); Males (n=32).

Appendix B

Table B.1 and Table B.2

Table B.2
Means, standard deviations, and one-way between groups ANOVA statistics for the study variables.

Variable	NPHE		OPHE		BPHE				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2, 68)	*p*	η^2
Sense of belonging									
Time 1	4.13	0.60	3.89	0.73	4.01	0.60	0.42	.657	.01
Time 2	4.10	0.77	3.73	0.83	3.81	0.67	0.68	.511	.02
Time 3	4.01	0.80	4.20	0.63	4.07	0.64	0.35	.709	.01
Time 4	3.98	0.74	4.09	0.70	3.90	0.74	0.46	.636	.01
Science confidence									

(continued on next page)

Table B.2 (*continued*)

Variable	NPHE		OPHE		BPHE				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2, 68)	*p*	η^2
Time 1	3.85	0.28	4.03	0.61	4.05	0.54	0.44	.649	.01
Time 2	3.79	0.47	3.44	0.86	3.57	0.82	0.49	.615	.01
Time 3	3.77	0.67	3.89	0.59	3.86	0.63	0.09	.914	.00
Time 4	3.92	0.73	3.87	0.65	3.69	0.85	0.51	.606	.01
Generic skills									
Time 1	4.31	0.71	4.24	0.70	4.07	0.60	0.72	.492	.02
Time 2	3.55	0.83	3.45	0.90	3.51	0.91	0.04	.962	.00
Time 3	3.74	1.32	4.03	0.93	3.89	0.83	0.29	.751	.01
Time 4	3.81	1.17	4.08	0.92	3.70	0.79	1.22	.302	.03
Loneliness									
Time 1	2.71	0.83	2.37	0.91	2.52	0.83	0.43	.651	.01
Time 2	2.90	1.07	2.33	0.90	2.60	0.93	1.01	.371	.03
Time 3	2.81	1.15	2.02	0.88	2.38	0.90	2.01	.142	.06
Time 4	2.95	1.41	2.08	0.91	2.43	0.97	1.94	.151	.05

Note. NPHE = No parent has higher education (n=7); OPHE = One parent has higher education (n=17); BPHE = Both parents have higher education (n=47)

Appendix C

Scales and items used in the study "Cooperative Learning Goes Online: Teaching and Learning Intervention in a Digital Environment Impacts Psychosocial Outcomes in Biology Students"

Science confidence scale (Lopatto, 2004; Seymour et al., 2004)

I am confident I can...

1. Discuss scientific concepts with my friends or family
2. Think critically about scientific findings I read about in the media
3. Read the scientific literature (current papers, written by scientists, in scientific journals)
4. Determine what is - and is not - valid scientific evidence
5. Make an argument using scientific evidence
6. Interpret tables and graphs
7. Pose questions that can be addressed by collecting and evaluating scientific evidence
8. Collect research-related data
9. Analyze data
10. Present scientific results in writing or orally
11. Understand scientific processes behind important scientific issues in the media
12. Understand the science content of this course
13. Use scientific thinking to solve problems outside of this course

Likert-scale ranging from 1 (strongly disagree), 2 (partly disagree), 3 (neither agree nor disagree), 4 (partly agree), to 5 (strongly agree)

(Perceived) generic skills (Ramsden, 1991)

1. The course developed my problem-solving skills
2. The course sharpened my analytical skills
3. The course helped me to develop my ability to work as a team member
4. As a result of my course, I feel confident about tackling unfamiliar problems
5. The course improved my skills in written communication
6. The course helped me to develop my ability to plan my own work

Likert-scale ranging from 1 (strongly disagree), 2 (partly disagree), 3 (neither agree nor disagree), 4 (partly agree), to 5 (strongly agree)

Sense of belonging (Goodenow, 1993)*

1. I feel like a real part of this course
2. It is hard for people like me to be accepted here
3. Other students in this course take my opinions seriously
4. Most teachers in this course are interested in me
5. Sometimes I feel as if I don't belong here
6. There's at least one teacher or other adult in this course I can talk to if I have a problem

7 People in this course are friendly to me
8 Teachers here are not interested in people like me
9 I am included in lots of activities in this course
10 I am treated with as much respect as other students
11 I feel very different from most other students here
12 I can really be myself in this course
13 The teachers here respect me
14 I wish I were in a different course
15 I feel proud of belonging to this course
16 Other students here like me the way I am

Likert-scale ranging from 1 (strongly disagree), 2 (partly disagree), 3 (neither agree nor disagree), 4 (partly agree), to 5 (strongly agree)

*Items adapted to the studied course (not school) and two items removed

Loneliness short item scale (Hughes et al., 2004)

1 How often do you feel that you lack companionship?
2 How often do you feel left out?
3 How often do you feel isolated from others?

Likert-scale ranging from 1 (never), 2 (rarely), 3 (sometimes), 4 (often), to 5 (very often)

References

Aakre, I. G., & Mørkve, M. S. (2021). *Det er lurt å skrive en avtale! Ferske studenters opplevelse av gruppearbeid og gruppeavtaler.* MNT conference, University of Agder.

Abdul Karim, A. M., Abdullah, N., Abdul Rahman, A. M., Noah, S. M., Wan Jaafar, W. M., Othman, J., Borhan, L., Badushah, J., & Said, H. (2012). A nationwide comparative study between private and public university students' soft skills. *Asia Pacific Education Review, 13*(3), 541–548. https://doi.org/10.1007/s12564-012-9205-1

Adriansen, H. K., & Madsen, L. M. (2012). Facilitation: A novel way to improve students' well-being. *Innovative Higher Education, 38*(4), 295–308. https://doi.org/10.1007/s10755-012-9241-0

Ainscough, L., Foulis, E., Colthorpe, K., Zimbardi, K., Robertson-Dean, M., Chunduri, P., & Lluka, L. (2016). Changes in biology self-efficacy during a first-year university course. *CBE Life Science Education, 15*(2), ar19. https://doi.org/10.1187/cbe.15-04-0092

Alkan, N. (2016). Psychological sense of university membership: An adaptation study of the PSSM scale for turkish university students. *The Journal of Psychology, 150*(4), 431–449. https://doi.org/10.1080/00223980.2015.1087373

Allen, K.-A., Kern, M. L., Rozek, C. S., McInerney, D. M., & Slavich, G. M. (2021). Belonging: A review of conceptual issues, an integrative framework, and directions for future research. *Australian Journal of Psychology, 73*(1), 87–102. https://doi.org/10.1080/00049530.2021.1883409

Appleton, J. J., Christenson, S. L., Kim, D., & Reschly, A. L. (2006). Measuring cognitive and psychological engagement: Validation of the student engagement instrument. *Journal of School Psychology, 44*(5), 427–445. https://doi.org/10.1016/j.jsp.2006.04.002

Ballantine, J., & McCourt Larres, P. (2007). Cooperative learning: A pedagogy to improve students' generic skills? *Education & Training, 49*(2), 126–137. https://doi.org/10.1108/00400910710739487

Ballen, C. J., Salehi, S., & Cotner, S. (2017b). Exams disadvantage women in introductory biology. *Plos One, 12*(10), Article e0186419-e0186419. https://doi.org/10.1371/journal.pone.0186419

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017a). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE—Life Sciences Education,, 16*(4), ar56.

Bandura, A. (1986). The explanatory and predictive scope of self-efficacy theory. *Journal of Social and Clinical Psychology, 4*(3), 359–373. https://doi.org/10.1521/jscp.1986.4.3.359

Bandura, A. (1997). *Self-efficacy: The exercise of control.* Freeman.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17–66). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-2324-5_2.

Binning, K. R., Kaufmann, N., McGreevy, E. M., Fotuhi, O., Chen, S., Marshman, E., … Singh, C. (2020). Changing social contexts to foster equity in college science courses: An ecological-belonging intervention. *Psychological Science, 31*(9), 1059–1070. https://doi.org/10.1177/0956797620929984

Bourn, D. (2018). *Understanding global skills for 21st century professions.* Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-319-97655-6_3

Burns, K. M., Burns, N. R., & Ward, L. (2016). Confidence - more a personality or ability trait? It depends on how it is measured: A comparison of young and older adults. *Frontiers in Psychology, 7*, 518. https://doi.org/10.3389/fpsyg.2016.00518

Byrne, M., & Flood, B. (2003). Assessing the teaching quality of accounting programmes: An evaluation of the Course Experience Questionnaire. *Assessment and Evaluation in Higher Education, 28*(2), 135–145. https://doi.org/10.1080/02602930301668

Børve, K., Straume, K., Smith, R., Surén, P., Samdal, O., & Hågensen, E. (2021). Tiltak for oppfølging av studenter ved fagskoler, høyskoler og universiteter under koronoapandemien [Initiatives to follow up students in higher education during the Corona pandemic]. https://www.regjeringen.no/contentassets/459df2260de74e57a9f1317bd0bb492f/tiltak-for-oppfolging-av-studenter-ved-fagskoler-hoyskoler-og-universiteter-under-pandemien.pdf.

Camerer, C. F., Dreber, A., Holzmeister, F., Ho, T.-H., Huber, J., Johannesson, M., Kirchler, M., Nave, G., Nosek, B. A., Pfeiffer, T., Altmejd, A., Buttrick, N., Chan, T., Chen, Y., Forsell, E., Gampa, A., Heikensten, E., Hummer, L., Imai, T., & Wu, H. (2018). Evaluating the replicability of social science experiments in Nature and Science between 2010 and 2015. *Nature Human Behaviour, 2*(9), 637–644. https://doi.org/10.1038/s41562-018-0399-z

Camfield, E. K., Schiller, N. R., & Land, K. M. (2021). Nipped in the bud: COVID-19 reveals the malleability of STEM student self-sfficacy. *CBE Life Science Education, 20*(2), ar25. https://doi.org/10.1187/cbe.20-09-0206

Canelas, D. A., Hill, J. L., & Novicki, A. (2017). Cooperative learning in organic chemistry increases student assessment of learning gains in key transferable skills. *Chemistry Education Research and Practice, 18*(3), 441–456. https://doi.org/10.1039/C7RP00014F

Cheruvelil, K. S., De Palma-Dow, A., & Smith, K. A. (2020). Strategies to promote effective student research teams in undergraduate biology labs. *The American Biology Teacher, 82*(1), 18. https://doi.org/10.1525/abt.2020.82.1.18
Cotner, S., Jeno, L. M., Walker, J. D., Jørgensen, C., & Vandvik, V. (2020b). Gender gaps in the performance of Norwegian biology students: The roles of test anxiety and science confidence. *International Journal of STEM Education, 7*(1), 1–10. https://doi.org/10.1186/s40594-020-00252-1
Cox, C. (2015). Incorporating more individual accountability in group activities in general chemistry. *Journal of College Science Teaching, 44*(3), 30–36. https://doi.org/10.2505/4/jcst15_044_03_30
Crano, W. D., Brewer, M. B., & Lac, A. (2015). *Principles and methods of social research*. New York: Routledge, 3rd ed. ed.
Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., Magni, P. A., & Lam, S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. *Journal of Applied Learning & Teaching, 3*(1), 1–20. https://doi.org/10.37074/jalt.2020.3.1.7
Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Los Angeles: SAGE, 4th ed.; International student ed.
Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334. https://doi.org/10.1007/BF02310555
Curşeu, P. L., Chappin, M. M. H., & Jansen, R. J. G. (2018). Gender diversity and motivation in collaborative learning groups: The mediating role of group discussion quality. *Social Psychology of Education, 21*(2), 289–302.
Cutrona, C. E. (1982). Transition to college: Loneliness and the process of social adjustment. In L. A. Peplau, & D. Perlman (Eds.), *Loneliness : A sourcebook of current theory, research and therapy*. New York: Wiley, Article 291309.
Czaja, R., & Blair, J. (2005). Designing surveys: A guide to decisions and procedures (2nd ed.). Thousand Oaks: Pine Forge.
Damşa, C., de Lange, T., Elken, M., Esterhazy, R., Fossland, T., Frølich, N., Hovdhaugen, E., Maassen, P., Nerland, M. B., Nordkvelle, Y. T., Stensaker, B., Tømte, C., Vabø, A., Wiers-Jenssen, J., Aamodt, P. O., & Stensaker, B. (2015). *Quality in Norwegian higher education: A review of research on aspects affecting student learning*. Nordic Institute for Studies in Innovation Research and Education (NIFU). https://nifu.brage.unit.no/nifu-xmlui/bitstream/handle/11250/2360199/NIFUreport2015-24.pdf?sequence=4&isAllowed=y.
Daniel, K. L. (2016). Impacts of active learning on student outcomes in large-lecture biology courses. *The American Biology Teacher, 78*(8), 651–655.
Davey, T., Meerman, A., Galán-Muros, V., Orazbayeva, B., & Baaken, T. (2018). The state of university-business cooperation in Europe (Final report). https://www.ub-cooperation.eu/.
Davidson, N. (2021). Synthesis of CL approaches and a multifaceted rationale for CL - past, present, and future. In N. Davidson (Ed.), *Pioneering perspectives in cooperative learning* (pp. 234–254). New York: Routledge.
Deng, J., Zhou, F., Hou, W., Silver, Z., Wong, C. Y., Chang, O., Drakos, A., Zuo, Q. K., & Huang, E. (2021). The prevalence of depressive symptoms, anxiety symptoms and sleep disturbance in higher education students during the COVID-19 pandemic: A systematic review and meta-analysis. *Psychiatry Research, 301*, Article 113863. https://doi.org/10.1016/j.psychres.2021.113863
Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Procedings of the National Academy of Sciences USA, 116*(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116
Espeland, V., & Indrehus, O. (2003). Evaluation of students' satisfaction with nursing education in Norway. *Journal of Advanced Nursing, 42*(3), 226–236. https://doi.org/10.1046/j.1365-2648.2003.02611.x
Espinosa, T., Miller, K., Araujo, I., & Mazur, E. (2019). Reducing the gender gap in students' physics self-efficacy in a team- and project-based introductory physics class. *Physical Review Physics Education Research, 15*(1).
European Commision. (2021). Digital education action plan (2021-2027): Resetting education and training for the digital age [Online]. Retrieved 16.06.22 from https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en.
European Commision. (2022). Complete guide to GDPR compliance. Retrieved 20.04.22 from https://gdpr.eu/.
Field, A. (2009). *Discovering statistics using SPSS: (and sex and drugs and rock 'n' roll* (3rd ed.). Los Angeles: SAGE.
Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). Los Angeles: SAGE.
Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Procedings of the National Academy of Science USA, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111
Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *The Journal of Experimental Education, 75*(3), 203–220. https://doi.org/10.3200/JEXE.75.3.203-220
Furuto, M. (2013). *A case study on a diverse college algebra classroom: Analyzing pedagogical strategies to enhance students' mathematics self-efficacy*. [Oregon State University]. ProQuest Disertation Publishing.
Furuto, M. A. (2017). Mathematics pedagogical strategies to create a positive college classroom community. *Malaysian Journal of Mathematical Sciences, 11*(1), 9–21.
Gillies, R. M. (2003). Structuring cooperative group work in classrooms. *International Journal of Educational Research, 39*(1), 35–49. https://doi.org/10.1016/S0883-0355(03)00072-7
Gillies, R. M. (2016). Cooperative learning: Review of research and practice. *Australian Journal of Teacher Education, 41*(3), 39–54.
Goodenow, C. (1993). The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in Schools, 30*(1), 79–90.
Guo, Y., Logan, H. L., Glueck, D. H., & Muller, K. E. (2013). Selecting a sample size for studies with repeated measures. *BMC Medical Research Methodology, 13*(1), 100–108. https://doi.org/10.1186/1471-2288-13-100
Hagerty, B. M. K., Lynch-Sauer, J., Patusky, K. L., Bouwsema, M., & Collier, P. (1992). Sense of belonging: A vital mental health concept. *Archives of Psychiatric Nursing, 6*(3), 172–177. https://doi.org/10.1016/0883-9417(92)90028-H
Hawkley, L. C., & Cacioppo, J. T. (2010). Loneliness matters: A theoretical and empirical review of consequences and mechanisms. *Annals of Behavioral Medicine, 40*(2), 218–227. https://doi.org/10.1007/s12160-010-9210-8
Hayley, A. C., Downey, L. A., Stough, C., Sivertsen, B., Knapstad, M., & Øverland, S. (2017). Social and emotional loneliness and self-reported difficulty initiating and maintaining sleep (DIMS) in a sample of Norwegian university students. *Scandinavian Journal of Psychology, 58*(1), 91–99. https://doi.org/10.1111/sjop.12343
Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour Economics, 19*(4), 451–464. https://doi.org/10.1016/j.labeco.2012.05.014
Henrie, C. R., Halverson, L. R., & Graham, C. R. (2015). Measuring student engagement in technology-mediated learning: A review. *Computers and education, 90*, 36–53. https://doi.org/10.1016/j.compedu.2015.09.005
Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, M. (2020). The difference between emergency remote teaching and online learning. *Educause Review*. https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning.
Hoffman, M., Richmond, J., Morrow, J., & Salomone, K. (2002). Investigating "sense of belonging" in first-year college students. *Journal of College Student Retention: Research, Theory & Practice, 4*(3), 227–256.
Houlden, S., & Veletsianos, G. (2020). *Coronavirus pushes universities to switch to online classes – but are they ready?*, 12.03. The Conversation https://theconversation.com/coronavirus-pushes-universities-to-switch-to-online-classes-but-are-they-ready-132728.
Hughes, M. E., Waite, L. J., Hawkley, L. C., & Cacioppo, J. T. (2004). A short scale for measuring loneliness in large surveys: Results from two population-based studies. *Research on Aging, 26*(6), 655–672. https://doi.org/10.1177/0164027504268574
Hammarlund, S. P., Scott, C., Binning, K. R., & Cotner, S. (2022c). Context matters: How an ecological-belonging intervention can reduce inequities in STEM. *BioScience, 72*(4), 387–396.
Händel, M., Stephan, M., Gläser-Zikuda, M., Kopp, B., Bedenlier, S., & Ziegler, A. (2020). Digital readiness and its effects on higher education students' socio-emotional perceptions in the context of the COVID-19 pandemic. *Journal of Research on Technology in Education*, 1–13. https://doi.org/10.1080/15391523.2020.1846147
IBM. (2021). *IBM SPSS Statistics for Macintosh, Version 27.0*. IBM Corp.
Jacobs, G. M., McCafferty, S. G., & Iddings, A. C. D. (2006). Roots of cooperative learning in general education. In G. M. Jacobs, S. G. McCafferty, & A. C. D. Iddings (Eds.), *Cooperative learning and second language teaching* (pp. 9–17). Cambridge University Press.

Jansen, E., van der Meer, J., & Fokkens-Bruinsma, M. (2013). Validation and use of the CEQ in The Netherlands. *Quality Assurance in Education, 21*(4), 330–343. https://doi.org/10.1108/QAE-11-2012-0041

Jeno, L. M., Raaheim, A., Kristensen, S. M., Kristensen, K. D. B., Hole, T. N., Haugland, M. J., & Mæland, S. (2017). The relative effect of team-based learning on motivation and learning: A self-determination theory perspective. *CBE Life Science Education, 16*(ar 59), 1–12. https://doi.org/10.1187/cbe.17-03-0055

Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Edina: Interaction Book Company.

Johnson, D. W., & Johnson, R. T. (2016). Cooperative learning and teaching citizenship in democracies. *International Journal of Educational Research, 76*, 162–177. https://doi.org/10.1016/j.ijer.2015.11.009

Johnson, D. W., & Johnson, R. T. (2018). Cooperative learning: The foundation for active learning. In S. M. Brito (Ed.), *Active learning: Beyond the future*. IntechOpen. https://doi.org/10.5772/intechopen.73460.

Johnson, D. W., Johnson, R. T., & Holubec, E. J. (1994). *Cooperative learning in the classroom*. Association for Supervision and Curriculum Development.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). *Active learning: Cooperation in the college classroom* (2nd ed.). Edina: Interaction Book Company.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in College Teaching, 25*(3-4), 85–118.

Kagan, S. (2021). The structural approach and Kagan structures. In N. Davidson (Ed.), *Pioneering perspectives in cooperative learning* (pp. 78–127). New York: Routledge.

Kember, D., Leung, D. Y. P., & Ma, R. S. F. (2007). Characterizing learning environments capable of nurturing generic capabilities in higher education. *Research in Higher Education, 48*(5), 609–632. https://doi.org/10.1007/s11162-006-9037-0

Knapstad, M., Heradstveit, O., & Sivertsen, B. (2018). Students' Health and Wellbeing Study 2018. SiO. https://www.studenthelse.no/tema/sosiale_forhold.

Kocak, R. (2008). The effects of cooperative learning on psychological and social traits among undergraduate students. *Social Behavior and Personality, 36*(6), 771–782. https://doi.org/10.2224/sbp.2008.36.6.771

Lashley, M. A., Acevedo, M., Cotner, S., & Lortie, C. J. (2020a). How the ecology and evolution of the COVID-19 pandemic changed learning. *Ecology and evolution, 10*(22), 12412–12417. https://doi.org/10.1002/ece3.6937

Lederer, A. M., Hoban, M. T., Lipson, S. K., Zhou, S., & Eisenberg, D. (2021). More than inconvenienced: The unique needs of U.S. college students during the COVID-19 pandemic. *Health Educuation and Behavior, 48*(1), 14–19. https://doi.org/10.1177/1090198120969372

Lee, H., Parsons, D., Kwon, G., Kim, J., Petrova, K., Jeong, E., & Ryu, H. (2016). Cooperation begins: Encouraging critical thinking skills through cooperative reciprocity using a mobile learning game. *Computers & Education, 97*, 97–115. https://doi.org/10.1016/j.compedu.2016.03.006

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79–122. https://doi.org/10.1006/jvbe.1994.1027

Lillejord, S., Børte, K., Nesje, K., & Ruud, E. (2018). *Learning and teaching with technology in higher education - a systematic review*. Knowledge Center for Education. https://www.uis.no/sites/default/files/inline-images/slbTVKbYroGY36QPKNy3PzogniywJ7zrgc6Jatku2uQCMD7Ndb.pdf.

Loh, R. C.-Y., & Ang, C.-S. (2020). Unravelling cooperative learning in higher education. *Research in Social Sciences and Technology, 5*(2), 22–39. https://doi.org/10.46303/ressat.05.02.2

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education, 3*(4), 270–277.

Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d'Apollonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66*(4), 423–458.

Male, S. A., Bush, M. B., & Chapman, E. S. (2011). An Australian study of generic competencies required by engineers. *European Journal of Engineering Education, 36*(2), 151–163. https://doi.org/10.1080/03043797.2011.569703

Maslow, A. H. (1968). *Toward a psychology of being* (2nd ed.). New York: D. Van Nostrand.

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology, 108*(3), 424–437. https://doi.org/10.1037/edu0000061

Matthews-Ewald, M. R., & Zullig, K. J. (2013). Evaluating the performance of a short loneliness scale among college students. *Journal of College Student Development, 54*(1), 105–109. https://doi.org/10.1353/csd.2013.0003

Mazur, C., Creech, C., Just, J., Rolle, C., Cotner, S., & Hewlett, J. (2021a). Teaching during COVID-19 times: A community college perspective. *Journal of Microbiology & Biology Education, 22*(1). https://doi.org/10.1128/jmbe.v22i1.2459

Millis, B. J. (2010). Why faculty should adopt cooperative learning approaches. In B. J. Millis (Ed.), *Cooperative learning in higher education: Across the disciplines, across the academy* (1st ed.). Sterling: Stylus.

Millis, B. J., & Cottell, P. G. (1998). *Cooperative learning for higher education faculty*. Westport: American Council on Education/Oryx.

Møgelvang, A., & Nyléhn, J. (2022a). Co-operative learning in undergraduate mathematics and science education: A scoping review. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-022-10331-0

Møgelvang, A. & Nyléhn, J. (2022b). Interdependence between perceived cooperative learning, sense of belonging, and generic skills in undergraduate STEM education. *Nordic Journal of STEM Education*. (Re-submitted).

Murdock-Perriera, L. A., Boucher, K. L., Carter, E. R., & Murphy, M. C. (2019). Places of belonging: Person- and place-focused interventions to support belonging in college. In M. B. Paulsen, & L. W. Pern (Eds.), *Higher education: Handbook of theory and research* (pp. 291–323). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-03457-3_7.

Nissen, J. M., & Shemwell, J. T. (2016). Gender, experience, and self-efficacy in introductory physics. Physical review. *Physics Education Research, 12*(2), Article 020105. https://doi.org/10.1103/PhysRevPhysEducRes.12.020105

Norwegian Centre for Research Data (NSD). (2021). *Data protection services*. Retrieved 20.04.22 from https://www.nsd.no/en/data-protection-services.

Oakley, B., Felder, R. M., Brent, R., & Elhajj, I. (2004). Turning student groups into effective teams. *Journal of Student Centered Learning, 2*(1), 9–34.

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science, 349*(6251), 1–8. https://doi.org/10.1126/science.aac4716

Parsazadeh, N., Ali, R., & Rezaei, M. (2018). A framework for cooperative and interactive mobile learning to improve online information evaluation skills. *Computers & Education, 120*, 75–89. https://doi.org/10.1016/j.compedu.2018.01.010

Peplau, L. A., & Perlman, D. (1982). Perspectives on loneliness. In L. A. Pepla, & D. Perlman (Eds.), *Loneliness : A sourcebook of current theory, research and therapy* (pp. 1–18). New York: Wiley.

Phillips, R., Seaborne, K., Goldsmith, A., Curtis, N., Davies, A., Haynes, W., McEnroe, R., Murphy, N., O'Neill, L., Pacey, C., Walker, E., & Wordley, E. (2022). Student loneliness through the pandemic: How, why and where? *The Geographical Journal, 188*(2), 277–293. https://doi.org/10.1111/geoj.12438

Piaget, J. (1985). *The equilibration of cognitive structures: The central problem of intellectual development*. University of Chicago Press.

Pilcher, L. A., Darren, L. R., Kgadi, C. M., & Potgieter, M. (2015). An inquiry-based practical curriculum for organic chemistry as preparation for industry and postgraduate research. *South African Journal of Chemistry, 68*, 236–244.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education, 5*(1), 10–14. https://doi.org/10.1186/s40594-018-0115-6

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. *International Journal of STEM Education*, 6(1), 1–13. 10.1186/s40594-019-0159-2.

Rambøll (2021). SurveyXact. Retrieved 19.10.2021 from https://www.surveyxact.no.

Ramsden, P. (1991). A performance indicator of teaching quality in higher education: The Course Experience Questionnaire. *Studies in Higher Education, 16*(2), 129–150. https://doi.org/10.1080/03075079112331382944

Rattanatumma, T., & Puncreobutr, V. (2016). Assessing the effectiveness of STAD model and problem based learning in mathematics learning achievement and problem-solving ability. *Journal of Education and Practice, 7*(12), 194–199.

Regional Committees for Medical and Health Research Ethics (REK). (2020). Guidance and Support. Retrieved 20.04.22 from https://www.norcrin.no/en/regional-committees-for-medical-and-health-research-ethics-rek/.

Richardson, T., Elliott, P., & Roberts, R. (2017). Relationship between loneliness and mental health in students. *Journal of Public Mental Health, 16*(2), 48–54. https://doi.org/10.1108/JPMH-03-2016-0013
Rittmayer, A. D., & Beier, M. E. (2008). Overview: Self-efficacy in STEM. *SWE-AWE CASEE Overviews, 1*(3), 12.
Rivera, N. (2013). *Cooperative learning in a community college setting: Developmental coursework in Mathematics*. [Arizona State University]. ProQuest Disertation Publishing.
Sahil, S. A. S., Hassan, H., & Ismail, W. R. W. (2020). Measuring student learning approaches and generic skills: A multi-group analysis of gender differences. *International Journal of Humanities and Social Sciences, 12*(5), 1–12.
Salehi, S., Berk, S. A., Brunelli, R., Cotner, S., Creech, C., Drake, A. G., & Ballen, C. J. (2021b). Context matters: Social psychological factors that underlie academic performance across seven institutions. *CBE Life Science Education, 20*(4), Article ar68-ar68. https://doi.org/10.1187/cbe.21-01-0012
Salehi, S., Cotner, S., Azarin, S. M., Carlson, E. E., Driessen, M., Ferry, V. E., & Ballen, C. J. (2019). Gender performance gaps across different assessment methods and the underlying mechanisms: The case of incoming preparation and test anxiety. *Frontiers in Education (Lausanne), 4*. https://doi.org/10.3389/feduc.2019.00107
Seymour, E., Hunter, A.-B., Laursen, S. L., & Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education, 88*, 493–534.
Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Belmont: Wadsworth, Cengage Learning.
Sivertsen, B. (2021). Students' Health and Wellbeing Study 2021. SiO. https://sioshotstorage.blob.core.windows.net/shot2018/SHOT2021.pdf.
Smith, C., & Bath, D. (2006). The role of the learning community in the development of discipline knowledge and generic graduate outcomes. *Higher Education, 51*(2), 259–286. https://doi.org/10.1007/s10734-004-6389-2
Smith, J. L., Lewis, K. L., Hawthorne, L., & Hodges, S. D. (2013). When trying hard isn't natural: Women's belonging with and motivation for male-dominated STEM fields as a function of effort expenditure concerns. *Personality and Social Psychology Bulletin, 39*(2), 131–143. https://doi.org/10.1177/0146167212468332
Stake, J. E., & Mares, K. R. (2005). Evaluating the impact of science-enrichment programs on adolescents' science motivation and confidence: The splashdown effect. *Journal of Research in Science Teaching, 42*(4), 359–375. https://doi.org/10.1002/tea.20052
Stewart-Brown, S., Evans, J., Patterson, J., Petersen, S., Doll, H., Balding, J., & Regis, D. (2000). The health of students in institutes of higher education: An important and neglected public health problem? *Journal of Public Health, 22*(4), 492–499. https://doi.org/10.1093/pubmed/22.4.492
Sæthre, H. Å. (2014). Å tilrettelegge for at studentene skal lykkes: En verktøykasse for utdanningsledere, studieadministrasjon, studenttillitsvalgte [Facilitating student succes: A toolbox for educational leaders, study administration, student representatives]. Haas1.
Taber, K. S. (2016). Learning generic skills through chemistry education. *Chemistry Education Research and Practice Journal, 17*, 225–228.
Thomas, L. (2012). *Building student engagement and belonging in higher education at a time of change*. P. H. Foundation. https://www.heacademy.ac.uk/system/files/what_works_final_report_0.pdf.
Tice, D., Baumeister, R., Crawford, J., Allen, K.-A., & Percy, A. (2021). Student belongingness in higher education: Lessons for professors from the COVID-19 pandemic. *Journal of University Teaching & Learning Practice, 18*(4), 2.
Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*(1), 89–125. https://doi.org/10.3102/00346543045001089
Tinto, V. (1993). *Leaving college: Rethinking the causes and cures of student attrition* (2nd ed.). Chicago: The University of Chicago Press.
Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Science Education, 13*(1), 6–15. https://doi.org/10.1187/cbe.13-12-0241
Tynjälä, P., & Gijbels, D. (2012). Changing world: Changing pedagogy. P. Tynjälä, M.-L. Stenström, & M. Saarnivaara. In P. Tynjälä, M. L. Stenström, & M. Saarnivaara (Eds.), *Transitions and transformations in learning and education* (pp. 205–222). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-2312-2_13.
UN. (2015). The 2030 agenda for sustainable development. Retrieved 20.04.22 from https://sdg4education2030.org/the-goal.
UNICEF. (2021). Adolescent education and skills. Retrieved 21.04.22 from https://www.unicef.org/education/skills-development.
Virtanen, A., & Tynjälä, P. (2019). Factors explaining the learning of generic skills: A study of university students' experiences. *Teaching in Higher Education, 24*(7), 880–894. https://doi.org/10.1080/13562517.2018.1515195
Virtanen, A., & Tynjälä, P. (2022). Pedagogical practices predicting perceived learning of social skills among university students. *International Journal of Educational Research, 111*, Article 101895. https://doi.org/10.1016/j.ijer.2021.101895
Walker, J. D., Cotner, S. H., Baepler, P. M., & Decker, M. D. (2008). A delicate balance: Integrating active learning into a large lecture course. *CBE Life Science Education, 7*(4), 361–367. https://doi.org/10.1187/cbe.08-02-0004
Watermeyer, R., Crick, T., Knight, C., & Goodall, J. (2021). COVID-19 and digital disruption in UK universities: Afflictions and affordances of emergency online migration. *Higher Education, 81*(3), 623–641. https://doi.org/10.1007/s10734-020-00561-y
Werner, A. M., Tibubos, A. N., Mülder, L. M., Reichel, J. L., Schäfer, M., Heller, S., … Beutel, M. E. (2021). The impact of lockdown stress and loneliness during the COVID-19 pandemic on mental health among university students in Germany. *Scientific Reports, 11*(1), 22637. https://doi.org/10.1038/s41598-021-02024-5
Wilton, M., Gonzalez-Niño, E., McPartlan, P., Terner, Z., Christoffersen, R. E., & Rothman, J. H. (2019). Improving academic performance, belonging, and retention through increasing structure of an introductory biology course. *CBE Life Sciences Education, 18*(4), ar53. https://doi.org/10.1187/cbe.18-08-0155
Wonch Hill, P., McQuillan, J., Talbert, E., Spiegel, A., Gauthier, G., & Diamond, J. (2017). Science possible selves and the desire to be a scientist: Mindsets, gender bias, and confidence during early adolescence. *Social Sciences, 6*(2), 55. https://doi.org/10.3390/socsci6020055
Yapici, I. U. (2016). Effectiveness of blended cooperative learning environment in biology teaching: Classroom community sense, academic achievement and satisfaction. *Journal of Education and Training Studies, 4*(4), 269–280.
Yimer, S. T., & Feza, N. N. (2020). Learners' conceptual knowledge development and attitudinal change towards calculus using jigsaw cooperative learning strategy ontegrated with GeoGebra. *International Electronic Journal of Mathematics Education, 15*(1).
Yu, S., Alper, H. E., Nguyen, A.-M., Brackbill, R. M., Turner, L., Walker, D. J., Maslow, C. B., & Zweig, K. C. (2017). The effectiveness of a monetary incentive offer on survey response rates and response completeness in a longitudinal study. *BMC Medical Research Methodology, 17*(1), 77. https://doi.org/10.1186/s12874-017-0353-1