“Feel free to ask”

Nudging to promote asking questions in the online classroom

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"Feel free to ask": Nudging to promote asking questions in the online classroom

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ABSTRACT

Asking questions is vital for learning, yet students seldom exhibit this behavior. Given the increasing presence of online classrooms in tertiary education, it is much needed to examine ways to encourage students to ask questions and increase their engagement. Despite the critical role of asking questions to enhance learning, little is known in research on promoting this behavior. Therefore, in this paper, we empirically tested the effect of nudging – a novel approach in education consisting of subtle interventions to change behavior – in online classrooms in tertiary education on question asking behavior, student engagement, and grades. In Experiment 1 (n = 1011), the teacher's virtual background prompted questions (*prompt nudge*), while in Experiment 2 (n = 449), the teacher set a goal for the students to ask one question per session (*goal-setting nudge*). We found a trend towards a positive effect of the *prompt nudge* on questions, but not on grades. Exploratory analyses revealed this was driven by students who already asked many questions. We found no effect of the *goal-setting nudge* on any measure, nor any effect in either experiment on student engagement. The findings demonstrate that the *prompt nudge* can be a possible useful and easy to implement tool to encourage questions in the online classroom.

The COVID-19 pandemic has had heavy repercussions on daily life around the globe. For education, most classes had to be moved online. This incurred the risk of lower quality in teaching and student-teacher interactions. In addition, students have to overcome more behavioral barriers in this context, such as lacking motivation for, being aware of, or understanding of the methods of online teaching (Zohra, Mohammed, & Raed, 2020). But also before the pandemic, students experienced difficulties when following a completely online course (Clow, 2013; Rizvi, Rienties, & Rogaten, 2018). During online classes, students are often less actively involved in their classes, which can lead to decreased motivation and understanding of the course material (Raed, Mohammed, & Zohra, 2021). Student participation (i.e., participating in discussions, asking questions, doing learning activities) drops in online classes compared to regular classes (Asgari et al., 2021; Lee & Choi, 2010), although these forms of interaction are necessary ingredients for a successful learning experience (Chi & Wylie, 2014). Student participation is an important driver for the success of online courses, as it positively relates to student performance (Jurik, Gröschner, & Seidel, 2013; Sedláček & Šeďova, 2020). Indeed, student participation is necessary for students to successfully complete online courses (Appleton, Christenson, & Furlong, 2008; Vayre & Vonthron, 2019). In this study, we focus on a core aspect of student participation, namely asking questions in the classroom, and do so in the context of tertiary education.

1. Asking questions

Asking questions plays a central role when acquiring new knowledge or skills, as the questions are indicative of the gaps between the student's current knowledge and the learning goal. Questions in the classroom help students and teachers alike in attaining educational goals (for an in-depth discussion of the importance of student-generated questions, see Chin & Osborne, 2008). Students, however, encounter behavioral barriers when they want to ask a question (Weijers, de Koning, Klatter, & Paas, 2023a; Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). For example, students hesitate because they do not want to interrupt the

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class for their questions, or fear what their peers think of the question. These behavioral barriers are present in all educational settings but are amplified by online education (Howland & Moore, 2002), as students are often less motivated with the course (Meeter et al., 2020) and experience practical issues preventing them from following the course optimally (Onyema et al., 2020). Therefore, students are less likely to ask questions during an online course. Getting a grip on these unasked questions is important to both teachers and students (Weijers, de Koning, Klatter, & Paas, 2023a) as the number of questions students in online education have, but not necessarily ask, is often high (Scapin & Marega, 2000).

Not only do students experience difficulties with asking questions, but teachers also have a hard time encouraging questions from their students to improve their learning experience. This is even more pressing in online classrooms, as a teacher's time and resources are scarcer in an online environment. Online sessions are often shorter, and teachers do not have access to their physical materials, or have difficulty transferring their learning methods to an online setting. To support asking questions in the online classroom while accounting for these practical concerns, in this study we considered nudging (Thaler & Sunstein, 2008) as a possible easy and simple tool for teachers to encourage their students to ask questions in the online classroom.

2. Nudging

Nudging is a tool from behavioral economics in which knowledge of human biases is used to design an environment that facilitates behavioral change. A nudge is defined as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid." (Thaler & Sunstein, 2008, p.6). Thaler and Sunstein (2008) explain nudging using dual process theory, which posits two distinctive types of cognitive processing of information (e.g., Evans & Stanovich, 2013), labeling these systems System 1 and System 2, terms introduced by Stanovich (1999) and popularized by Kahneman (2011). System 1 describes fast, irrational, effortless processing, while System 2 describes slow, conscious and controlled processing. System 1 makes use of heuristics and rules of thumb to make decisions, which are often biased because of that, while System 2 represents a more deliberate way of thinking. System 1 often determines behavior because it requires little effort, but is easily influenced by seemingly unimportant cues in specific environments. The central idea of nudging is using System 1 in a positive manner, by making small changes (nudges) in the environment that make use of the characteristics of System 1 to alter people's behavior in a predictable manner, guiding them towards the targeted behavior. An important element of nudging is that it leaves the target's freedom of choice intact: there is no coercion, nor are incentives involved, when changing behavior.

3. Nudging in the context of education

Nudging was initially popularized in policy making but has recently been applied successfully in educational environments (Weijers, de Koning, & Paas, 2021; Damgaard & Nielsen, 2018). In this context, nudging is both used as a tool for educational policy makers and as an in-class tool, adding onto existing pedagogical interventions by making use of knowledge from the field of behavioral economics (Weijers, de Koning, Klatter, & Paas, 2023a). Changing students' behavior has been a focus of pedagogy for a longer time – e.g., theories of how self-regulation leads to autonomous learning behaviors (De Bruijn-Smolders, 2017; Zimmerman, 2002) and theories on student motivation (Heckhausen & Heckhausen, 2008; Ryan & Deci, 2020). Both perspectives can add to creating successful interventions to change student behavior. However, earlier reviews of nudging in education (e.g., Damgaard & Nielsen, 2018; Lim & Lee, 2022) do not interpret nudging through the lens of pedagogy. We therefore want to explicitly introduce nudging into the pedagogical field as a tool for behavior change, so that it can be tested and coupled with existing pedagogical paradigms about student behavior. The paradigms have different focuses: the behavioral economics perspective focuses on intervention implementation or transparency, the pedagogical perspective on how the intervention fits within fostering students' skills and competences. In practice, teachers can use techniques from both fields to enhance their courses. For a more thorough discussion on how nudging can fit into the field of education, see Weijers, de Koning, and Paas (2021).

In previous studies of nudging in education, nudging successfully changed students' behavior. For example, a nudge that asked students to set a personal goal for the number of practice exams they would complete, increased practice exam completion (Clark, Gill, Prowse, & Rush, 2020). Similarly, Castleman and Page (2015) increased college enrolment by providing personalized prompts that reminded high school students about the enrolment process. A recent study (Weijers, de Koning, Vermetten, & Paas, 2023b) showed that nudging was promising for changing in-class behavior, by increasing the number of questions students asked. In this study, students received a *goal-setting nudge*: they were asked by the teacher to ask at least one question during the session, which resulted in more questions being asked. Summarizing, different nudges have been successfully implemented to change different behaviors in educational settings.

Previous studies also showed that not every nudge is equally effective for each context. When designing a nudge, the specific targeted behavior and its specific context should be considered (Hansen, 2018). For this specific context – the online classroom – we must consider the restraints that are inherent to this environment. A teacher in an online learning environment has minimal control over the students' physical environment and establishing a connection with the student is difficult (Onyema et al., 2020). On the positive side, the teacher has a high degree of control over the design of the learning environment. Furthermore, Weijers, de Koning, and Paas (2021) recommend a transparent nudge for educational contexts, i.e., nudges of which the intent is easily recognizable. Transparent nudges are preferred over non-transparent nudges, as it allows nudgees to recognize the influence attempt, reducing ethical concerns. Based on these factors, we identified and tested two promising nudge types in this study: the *prompt* nudge and the *goal-setting* nudge, for asking questions in the online classroom.

The first type is an intervention that the field of behavioral economics calls a *prompt nudge*, i.e., an "environmental or social stimulus with the purpose of prompting or cueing the behavior" (Michie, Atkins, & West, 2014, p. 268) that is usually present at the time or place of performance (Michie et al., 2014). Often, this nudge consists of a poster or sticker that serves as a reminder of the behavior. The effect of the prompt is usually explained by the attention drawn to the cue, serving as a visual call to action (Holmes, 2009), disrupting habits and counteracting forgetting (Dewies, Schop-Etman, Rohde, & Denktaş, 2021). Prompt nudges have been found to have a positive effect on different behaviors in an educational context by counteracting students' limited attention and cognitive ability (Damgaard & Nielsen, 2018). For example, prompts were able to encourage students' paper submission, their college enrolment, and forum contributions; for an overview, see Damgaard and Nielsen (2018). Within the pedagogical framework, prompts are also already widely used within educational contexts as a scaffolding technique to promote learning activities, called procedural prompts (Rosenshine, Meister, & Chapman, 1996), in order to facilitate students' self-regulated learning (Bannert, 2009). More specifically, a study by Schworm and Gruber (2012) found that providing procedural prompts to university students in a virtual workspace increased help-seeking behaviors like placing help requests, and improved their subsequent learning outcomes.

The second type is a *goal-setting nudge*, defined within behavioral economics as "set[ting] or agree[ing] a goal defined in the terms of the behaviors to be achieved" (Michie et al., 2014, p.259), which guides

people towards completing this goal (e.g., Weintraub, Cassell, & DePatie, 2021). Additionally, this nudge has shown to increase involvement (Weintraub et al., 2021). This nudge makes use of conscious goals, which can help to regulate behavior according to goal-setting theory (Locke & Latham, 2002). Setting specific rather than abstract goals leads to more success (Locke & Latham, 2002), suggesting that any larger goal (e.g., graduating) should be broken down into smaller goals (e.g., asking a question during a session) (Höchli, Brügger, & Messner, 2018). From the perspective of pedagogy, goal-setting is practiced to increase self-regulation in students (Zimmerman, 2002) by increasing their self-efficacy and motivation (Schunk, 2001). For example, guiding students using goal-setting techniques in an online course improved their self-regulatory behaviors (Weijers, Ganushchak, Ouwehand, & de Koning, 2022). Setting these goals for students has been practiced in education successfully to change different behaviors, such as class attendance (Duckworth, Kirby, Gollwitzer, & Oettingen, 2013) and practice exam completion (Clark et al., 2020). Furthermore, goal-setting has already been shown to increase both students' questions asked and subsequent learning outcomes in the physical classroom (Weijers, de Koning, Vermetten, & Paas, 2023b). This intervention consisted of a teacher asking their students at the start of each class to try and ask at least one question during the session, and tracked the number of questions each student asked. Students who received this intervention asked more questions – although this finding was marginally significant - and achieved significantly higher grades. However, this was done in a physical classroom and with a relatively small sample size. The current study will expand upon these findings by investigating whether a goal-setting nudge for asking questions can be effective in an online classroom, as students are typically more passive in this setting (Asgari et al., 2021; Lee & Choi, 2010). Therefore, in the present study, we aim to replicate this study with a larger sample in an online context.

4. Effect of nudges on student engagement

In this research, we will focus on the effect of two nudges – the prompt nudge and the goal-setting nudge - on asking questions. Additionally, we will investigate the effect of these nudges on a broader concept that is related to asking questions: student engagement. Student engagement and verbal participation in class (e.g., asking questions) are correlated (Cho & Cho, 2014; Frymier & Houser, 2016), but engagement is a broader concept than verbal participation (Christenson, Reschly, & Wylie, 2012; Frymier & Houser, 2017). Student engagement is an important predictor of academic achievement (Skinner, Furrer, Marchand, & Kindermann, 2008; Jang, Reeve, Ryan, & Kim, 2009) and dropout (Lee & Choi, 2010). Because of this, we deem student engagement an important overarching factor to consider when investigating a nudge aimed at increasing students' asking questions behavior in the classroom. Furthermore, because appropriate support, like scaffolding, can increase engagement (Cho & Cho, 2014), we expect the prompt nudge and the goal-setting nudge to also increase student engagement.

Student engagement can be classified into various types of engagement (e.g., Reeve, 2013; Skinner et al., 2008). In this study, we focused on two types of student engagement that seem most relevant for students' active participating behavior in the form of asking questions: behavioral and agentic engagement. Behavioral engagement refers to "active participation in the school setting" (Elffers, 2013, p. 547). Agentic engagement is "students' constructive contribution into the flow of the instruction they receive" (Reeve & Tseng, 2011, p. 258), meaning the degree to which students themselves take initiative to indicate what they want to learn. We investigate these forms of engagement for three reasons. First, behavioral engagement is linked to student-teacher interaction (Nguyen, Cannata, & Miller, 2018), as well as academic achievement (Gregory, Allen, Mikami, Hafen, & Pianta, 2014) and reduced dropout risk (Archambault, Janosz, Fallu, & Pagani, 2009). Agentic engagement is linked to classroom interactions (Montenegro, 2019; Reeve, 2012), skill development (Reeve et al., 2021) and academic achievement (Reeve, Cheon, & Jang, 2020). These findings correspond with the previously outlined importance of student engagement for verbal participation (Frymier & Houser, 2016), academic achievement (Christenson et al., 2012), and dropout (Lee & Choi, 2010). Second, we suspect that, should the nudge be successful in promoting asking questions, this effect could create more student engagement (Cho & Cho, 2014) and even spill over to other, similar behaviors that are also reflected in the engagement scales (called spillover behaviors, Dolan & Galizzi, 2015). For example, a student who is nudged to ask questions in class may also be more likely to pay attention (reflecting increased behavioral engagement) or to express their opinion to the teacher (reflecting increased agentic engagement). Third, including these measures also corresponds with the call to not focus more on the processes underlying educational outcomes in educational research, instead of just on the outcomes (Weijers, de Koning, & Paas, 2021; Ruggeri, 2019).

Given the positive results of Weijers, de Koning, Vermetten, and Paas (2023b), the found correlation between high participation and student achievement (Jurik et al., 2013; Sedláček & Šeďova, 2020) and the practical relevance for both teachers and students, we also investigate the possible effect of the nudges on learning outcomes.

5. Current study

Asking questions in the classroom is a core aspect of student classroom participation and a central behavior in learning (Chi & Wylie, 2014; Chin & Osborne, 2008). However, students struggle with displaying this behavior (Weijers, de Koning, Klatter, & Paas, 2023a; Aleven et al., 2003), especially in online settings (Howland & Moore, 2002; Meeter et al., 2020, Onyema et al., 2020). In this research, we identify nudging as a possible new avenue for teachers to support their students in displaying asking questions during online classes. Previous studies outline the potential effectiveness of the *prompt nudge* (Damgaard & Nielsen, 2018; Michie et al., 2014). Specifically, Schworm and Gruber (2012) successfully provided students with prompts to promote help-seeking behavior. The *goal-setting nudge* seems also promising to change behavior (Locke & Latham, 2002) in an educational context (e.g., Clark et al., 2020; Duckworth et al., 2013). An earlier experiment (Weijers, de Koning, Vermetten, & Paas, 2023b) found that a *goal-setting nudge* increased questions asked in a physical classroom, but it is unclear whether this effect persists in an online setting. No research has been done on using a *prompt nudge* and a *goal-setting nudge* to promote asking questions during class in an online context. Furthermore, we focus on two forms of student engagement: behavioral (Elffers, 2013) and agentic (Reeve & Tseng, 2011). These forms of engagement are linked to classroom interaction (Montenegro, 2019; Nguyen et al., 2018; Reeve, 2012) and possibly affected by the nudge (Cho & Cho, 2014; Dolan & Galizzi, 2015). Lastly, learning outcomes may also be affected by the

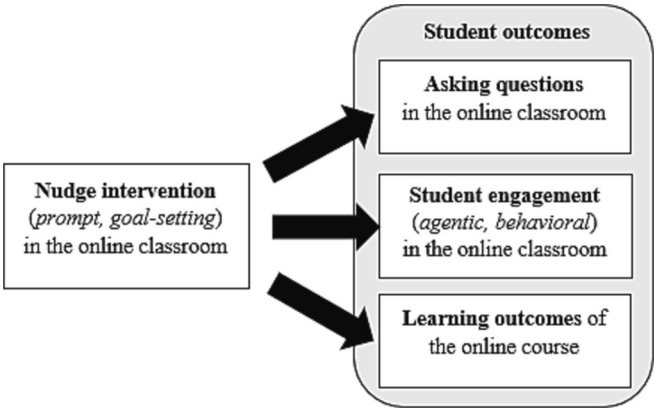

Fig. 1. Overview of Relevant Variables in This Study.

nudges (Weijers, de Koning, Vermetten, & Paas, 2023b). An overview of the central variables in this study can be found in Fig. 1.

Based on these earlier findings, we formulated the following research question: *can a nudge (either a goal-setting nudge or a prompt nudge) promote students' question asking, engagement, and learning outcomes in an online classroom setting?* We tested these two intervention types (*prompt nudge* and *goal-setting nudge*) in online classrooms. Thereby introducing nudges in an online learning environment targeted at students' participation, by measuring both questions asked, student engagement, and learning outcomes. Based on the previously described findings, the following specific hypotheses for this study were formulated:

Hypothesis 1. Students who receive a *prompt nudge* (a) ask more questions, (b) report more behavioral engagement, (c) report more agentic engagement and (d) receive higher grades than students in the control condition, who do not receive the nudge.

Hypothesis 2. Students who receive a *goal-setting nudge* (a) ask more questions, (b) report more behavioral engagement and (c) report more agentic engagement and (d) receive higher grades than students in the control condition, who do not receive the nudge.

The hypotheses for each nudge were tested in separate experiments. We also included several exploratory measures in these experiments. First, we speculated a student's extraversion is a predictor of asking questions. In an educational context, student extraversion was found to be related to their participation in online classes (Quigley, Bradley, Playfoot, & Harrad, 2022), although a study by Sulea, Van Beek, Sarbescu, Virga, and Schaufeli (2015) did not find a link of extraversion with student engagement. In contrast, introversion is related to passiveness (Offir, Bezalel, & Barth, 2007) and the preference for anonymous participation in the classroom (Latham & Hill, 2014). For example, student's degree of introversion was related to speaking anxiety (Dewaele, 2013) and a reluctance to volunteer (McAvoy-Yau & Kelly, 2019). Therefore, student extraversion is potentially linked to asking more questions. Furthermore, extraversion is linked to goal achievement (McCabe & Fleeson, 2012), and engagement interventions may have a different effect on extraverted versus introverted students (e.g., Sawang, O'Connor, & Ali, 2017), making extraversion a possible moderator of the nudge's effectiveness.

Second, to complement the objective assessment with subjective student experiences, we measured self-reported difficulty asking questions, as well as students' self-reported estimate of their own average number of questions asked in a lesson, as a measure of calibration (Hattie, 2013). This allowed us to see to what degree students are calibrated (i.e., the discrepancy between their reported number of questions asked, their reported difficulty with asking questions, and the number of questions they actually ask). Earlier research shows that students have trouble with monitoring their own performance accurately (e.g., Baars, Wijnia, de Bruin, & Paas, 2020; Van Loon, de Bruin, van Gog, van Merriënboer, & Dunlosky, 2014) because they use poor cues. However, learning performance is often abstract, which makes it difficult to identify the appropriate cues (Van Laer & Elen, 2019). With this exploratory measure, we investigated whether this misjudgment is also present for concrete behavior (i.e., asking questions in class) which should have very accessible cues to judge performance by.

6. Method

To promote asking questions, two nudge interventions were designed: a *prompt nudge* (Experiment 1) and a *goal-setting nudge* (Experiment 2). Both interventions targeted asking questions during class. The interventions were tested in separate experiments. Apart from the intervention itself, the method of the two experiments was identical, and is discussed below. Results are discussed separately. Teachers from all levels in tertiary education (vocational education and training [VET], higher vocational education [HVE], and university) were recruited for participating in the study. Teachers were recruited via email and word-of-mouth from schools participating within a larger consortium that investigated the practical application of nudging in education. Participating teachers indicated the intervention they wanted to implement in their classroom (*prompt nudge* or *goal-setting nudge*) and submitted a list of their available and suitable classes to the primary researcher. As the interventions were class-wide, stratified condition randomization of the intervention (experimental or control) took place on a class level, with the restriction that a teacher's classes were divided evenly between the two conditions. We divided "parallel" classes between the conditions (i.e., if a teacher taught English to two groups of first year students, one of these groups were put in the control condition and the other in the experimental condition). Then, the remaining classes were divided based on course content, number of class sessions, class sizes, education level, and year of educational program, to keep these factors as comparable as possible between conditions. This was done manually by the primary researcher. This resulted in two separate data sets, one for each nudge. The difference between the experimental groups on different factors is shown in Table 1. Due to the availability of participating teachers and class scheduling, no perfect balance was possible, but because of the parallel class setup, the conditions balance out quite evenly. Due to the way classes are scheduled, session length (class duration) is the same across classes in the same school. The potential difference between session length between schools is accounted for in the analysis (see Analysis).

This research took place during the same semester, between January and June 2021, in four institutes for tertiary education (two VET-schools, one HVE-school, and one university). During this semester, teachers taught a course to their students in a digital classroom environment, usually Teams or Zoom. The length of a semester varied between schools and was between five to ten weeks. As schedules differed between schools and courses, not all classes followed an equal number of sessions (see Table 1). The data collection for both studies and both conditions ran in parallel.

6.1. Participants

For the *prompt nudge* (Experiment 1), 1043 students in tertiary education participated in this research. Of these 1043 participants, 32 students were removed from the dataset due to large (>50%) absence, leaving 1011 students in the final sample, of which 518 in the nudge condition and 493 in the control condition. In the final sample, 447 students were in VET, 157 in HVE, and 407 were university students. In total, 20 classes participated in the nudge condition, and 20 classes participated in the control condition. The average class contained 26 students. The classes were taught by 15 teachers, of which 6 in VET, 2 in HVE and 7 in university.

For the *goal-setting nudge* (Experiment 2), 488 students in tertiary education participated. Of the 488 participants, 39 students were removed from the data due to large (>50%) absence, leaving 449 students in the final sample. Of these students, 204 were in the control condition and 245 in the nudge condition. In the final sample, 237 of

Table 1
Differences Between the Experimental Groups after Randomization.

	Prompt Control	Experiment	**Goal-setting** Control	Experiment
Number of classes	20	20	11	14
Average number of sessions	6.20	6.35	4.81	5.21
Students in VET	215	232	61	95
Students in HVE	84	73	117	120
Students in University	194	213	26	30
Average class size	24.65	25.90	18.55	17.50
Average year of study	1.90	1.75	1.71	1.60

these students were in VET, 156 in HVE, and 56 were university students. In total, 14 classes participated in the nudge condition, and 11 classes in the control condition. The average class contained 20 students. There were 9 teachers who participated in the experiment, of which 6 in VET, 2 in HVE and one in university.

6.2. Design

The research design was approved by the Ethics Committee of [name university – details removed for peer review]. Both studies had a between-subjects design with two conditions: a nudge condition and a control condition. The nudge condition consisted of a prompt nudge (Experiment 1) or a goal setting nudge (Experiment 2). The dependent variables were questions asked, student engagement, and grades. All measures were collected on an individual level. Specific student demographics like age and gender were not collected.

For the *prompt nudge* (Experiment 1), the teacher taught their regular class online, and used the digital classroom tool (most often Microsoft Teams/Zoom) to change their virtual background into a prompt to ask questions. Teachers received a virtual background to use, but could opt to make adjustments based on personal taste (e.g., some teachers chose to adapt their department's existing virtual background by adding the prompt message). This virtual background contained the message "Question? Ask live or in chat!" clearly visible (see Fig. 2 for an example). This background was used during all classes throughout the entire session for students in the nudge condition. In the control condition, teachers used either no virtual background or the virtual background they would normally use (i.e., without a message).

For the *goal-setting nudge* (Experiment 2), the teacher set a goal every session: all students should aim to ask at least one question in the session. At the start of each session, this goal was explicitly mentioned verbally, phrased in a way that the teacher felt appropriate. Students were informed that there was no negative consequence for not achieving this goal. Other than that, the content of the sessions was the same for the experimental and the control conditions.

6.3. Procedure

Students were informed about the experiment by their teacher, and informed of the possibility to opt out of their data being used for the study. Students then received the regular curriculum (the experimental condition with the nudge intervention, the control condition without the nudge intervention), and underwent the same data collection. For both conditions, the teacher scheduled five minutes in the first and last class of the semester to distribute the online pre- and post-measurement survey. In this survey, students were first asked for informed consent, and were asked their name, curriculum, class, course, and teacher. Then, students filled in the measurements for behavioral and agentic engagement (pre- and post-measurement) and the exploratory measures (pre-measurement only, see Appendix A).

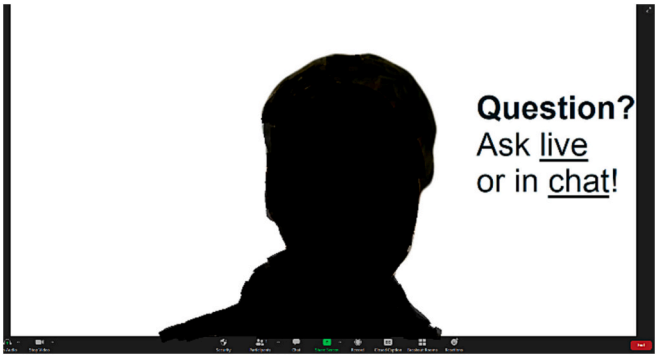

Fig. 2. Example of the Prompt Nudge in use by a Teacher in a Zoom Virtual Environment.
Note: The teacher is indicated with a silhouette.

For the *prompt nudge* (Experiment 1), a total of 194 students (19.2% of the sample) had filled in both surveys, making them eligible for Hypothesis 1b and 1c. Of these students, 100 were in the control condition and 94 in the nudge condition. For the *goal-setting nudge* (Experiment 2), a total of 71 students (14.5% of the sample) had filled in both surveys, making them eligible for Hypothesis 2b and 2c. Of these students, 28 were in the control condition and 43 in the nudge condition.

6.4. Measures

6.4.1. Asking questions

The number of questions an individual student asked was registered, resulting in a score per student per session. Each time a question was asked, the teacher noted this as one question and indicated who asked the question. All questions, apart from necessary procedural questions (e.g., "Can I go to the bathroom?" or "Is my microphone on?"), were counted. To avoid potential effects of students feeling observed, students were not informed in advance that their number of questions was scored individually. After the experiment, teachers were asked if they encountered difficulties with this registration. No difficulties were reported.

6.4.2. Engagement

A survey was used to measure behavioral engagement and agentic engagement. To measure behavioral engagement, the scale developed by Elffers (2013) was used. This scale consists of eight items measured on a five-point Likert scale (1 = completely disagree, 5 = completely agree). If necessary, the item was reworded to fit an online classroom context. An example item is "I pay close attention during class". To measure agentic engagement, the scale developed by Reeve (2013) was used. This scale consists of five items measured on a five-point Likert scale (1 = completely disagree, 5 = completely agree). An example item is "I let my teachers know what I need and want". For both scales, an average score was calculated. All instances of these measurements were reliable ($\alpha > 0.70$; Gliem & Gliem, 2003) apart from the exploratory measure Extraversion (See Table 2).

6.4.3. Grades

Teachers were asked to provide the researchers with a single grade that best represented an individual student's performance for the course. This was the grade for an exam or an assignment at the end of the course. If the grade was non-numerical (e.g., "sufficient or "good"), the Dutch conversion system was used to convert these grades into numbers (e.g., "good" was converted to an 8 on a 10-point scale). Not every course was associated with a usable grade (e.g., the course only used pass/fail, or only had a participating requirement) or teachers indicated that the final grade was not representative of the class sessions of the courses. For these students, no grade was collected. For the *prompt nudge* (Experiment

Table 2
Cronbach's Alpha of the Engagement Measures and Extraversion in Experiment 1 and 2.

	Cronbach's alpha	
	Experiment 1 (prompt)	Experiment 2 (goal-setting)
Behavioral Engagement – pre-measurement	0.75	0.69
Behavioral Engagement – post-measurement	0.77	0.71
Agentic Engagement – pre-measurement	0.83	0.76
Agentic Engagement – post-measurement	0.86	0.82
Extraversion	0.61	0.65

1), grades were collected from 646 students (63.9% of the total sample), of which 307 in the control condition and 339 in the nudge condition. For the *goal-setting nudge* (Experiment 2), grades were collected from 233 students (51.9% of the total sample), of which 97 in the control condition and 136 in the nudge condition.

6.4.4. Exploratory measures

In an exploratory fashion, extraversion and self-reported question behavior were measured. Extraversion was measured with the Dutch version of the extraversion subscale of the BIG-10 (Denissen, Geenen, Van Aken, Gosling, & Potter, 2008; original version by Rammstedt & John, 2007), consisting of two items rated on a five-point Likert scale. These items were "I see myself as someone who is outgoing, sociable" and "I see myself as reserved" (item reversed). For self-reported question asking, two questions were added to the survey. One question asked for the students' perceived difficulty of asking questions during an online class (on a five-point Likert scale). The other question asked for an estimation of average asked questions during an online class. These exploratory measures were only included in the pre-measure survey, as they were expected to be stable traits throughout the intervention. For the *prompt* nudge (Experiment 1), the effect of extraversion was investigated in the subset of students who filled in the first questionnaire, as this questionnaire contained all relevant measurements. These data were collected from 405 students, of which 179 in the control condition and 226 in the nudge condition. Of the students who filled in the pre-measurement survey, 253 received the version in which the self-reported question behavior section was added, of which 101 in the control condition and 152 in the nudge condition. For the *goal-setting* nudge (Experiment 2), extraversion was measured in 223 students, of which 87 in the control condition and 136 in the nudge condition. The version in which the self-reported question behavior section was added, was filled in by 170 students, of which 64 in the control condition and 106 in the nudge condition.

6.5. Analysis

The hypotheses were investigated using a mixed effects model approach in the statistical program R (R Core Team, 2020), using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015), with condition (control or nudge) as the independent variable for all hypotheses. For Hypotheses 1a and 2a, the dependent variable was the number of questions asked per student per session, and data was converted to a long format per separate data point for the dependent variable. For Hypotheses 1b-c and 2b-c, the dependent variable was behavioral and agentic engagement, respectively. The data was converted to a long format per survey (pre- and post-measure) to add the effect of the repeated measure to the model. For Hypotheses 1d and 2d, the dependent variable was students' final grade, and the number of questions a student asked was averaged over the number of sessions they were present.

The variable class ID, and student ID were included as random intercept, teacher ID as fixed intercept, and session ID as random slope, to account for the nested nature of the data. For the analysis of Hypotheses 1d and 2d, the number of questions asked was added as fixed intercept. The suggestions of Barr, Levy, Scheepers, and Tily (2013) were then used as a guideline to optimize the random structure. Assumptions for the relevant analyses were tested and found not violated. In case of singularity warnings, the advice of Bolker (n.d.) was followed. No problematic instances of singularity occurred. To determine *p*-values, the parametric bootstrap function of the package afex (Singmann, Bolker, Westfall, Aust, & Ben-Shachar, 2015) was used. The preregistration of the analysis, as well as the used data and scripts used for analysis, can be found on the Open Science Framework (https://osf.io/hmujz/?view_only=bc766f6b2b1c46faae2a6ae5a1da9409).

7. Results

7.1. Experiment 1 – prompt nudge

7.1.1. Questions asked

The average student asked 0.56 questions per session ($SD = 0.92$). When investigating Hypothesis 1a, we found a positive trend of the effect of the prompt nudge on asking questions: students in the nudge condition ($M = 0.61$, $SD = 1.02$) asked more questions per session (*Estimate* $= 0.07$, $SE = 0.04$, $t(908.20) = 1.73$, $p = .08$) than students in the control condition ($M = 0.50$, $SD = 0.80$), albeit not reaching statistical significance.

In an exploratory manner, no interaction of educational level was found on the effect of the nudge on the number of questions that a student asked ($F(2, 423.96) = 0.73$, $p = .48$), indicating that the effect of the nudge is present irrespective of the educational level in which it was tested. Additionally, the instances of a student asking more than four questions during a session (>3 standard deviations above the mean) were excluded from the data and the analyses was re-run. The positive trend of the nudge found initially then disappeared (*Estimate* $= 0.03$, SE $= 0.03$, $t(1002) = 1.07$, $p = .28$), indicating that the found trend was driven by students who are already asking the most questions.

7.1.2. Engagement

The descriptive statistics of the engagement measures can be found in Table 3 and Fig. 3. No significant interaction was found between condition (control, nudge) and time (pretest, posttest) for self-reported behavioral engagement (*Estimate* $= -0.02$, SE $= 0.01$, $t(191.84) = -1.61$, $p = .11$). This means that students in the nudge condition did not experience a change in their behavioral engagement that was different from the change that students in the control condition experienced. This finding rejects Hypothesis 1b. Similarly, no significant interaction was found between condition and time for self-reported agentic engagement (*Estimate* $= -0.03$, SE $= 0.02$, $t(192.93) = -1.55$, $p = .12$). Therefore, Hypothesis 1c was also rejected: students in the nudge condition did not experience a different change in their agentic engagement than students in the control condition.

In an exploratory fashion, a weak significant correlation of behavioral engagement with average number of questions asked was found ($r = 0.12$, $p = .02$), as well as a weak significant correlation of agentic engagement with average number of questions asked ($r = 0.10$, $p = .04$), indicating that these measures are indicative of question asking behavior.

7.1.3. Grades

Of the 646 students, the students' average final grade was 6.86 ($SD = 1.81$). We did not find support for Hypothesis 1d: students in the nudge condition ($M = 6.82$, $SD = 1.75$) did not obtain significantly higher grades (*Estimate* $= 0.09$, SE $= 0.12$, $t(34.27) = 0.81$, $p = .43$) than students in the control condition ($M = 6.90$, $SD = 1.88$). We found a direct effect of the average number of questions asked by a student on their final grade (*Estimate* $= 0.31$, SE $= 0.07$, $t(631.62) = 4.24$, $p < .001$), indicating that students who ask more questions, obtain higher final grades, regardless of the nudge intervention condition.

Table 3
Average and Standard Deviation of the Engagement Measures in Experiment 1.

	Pre-measurement	Post-measurement
Behavioral Engagement	4.09 (0.51)	3.94 (0.57)
control	4.07 (0.49)	3.95 (0.51)
nudge	4.12 (0.52)	3.92 (0.63)
Agentic Engagement	3.40 (0.68)	3.32 (0.76)
control	3.39 (0.64)	3.38 (0.71)
nudge	3.41 (0.72)	3.27 (0.81)

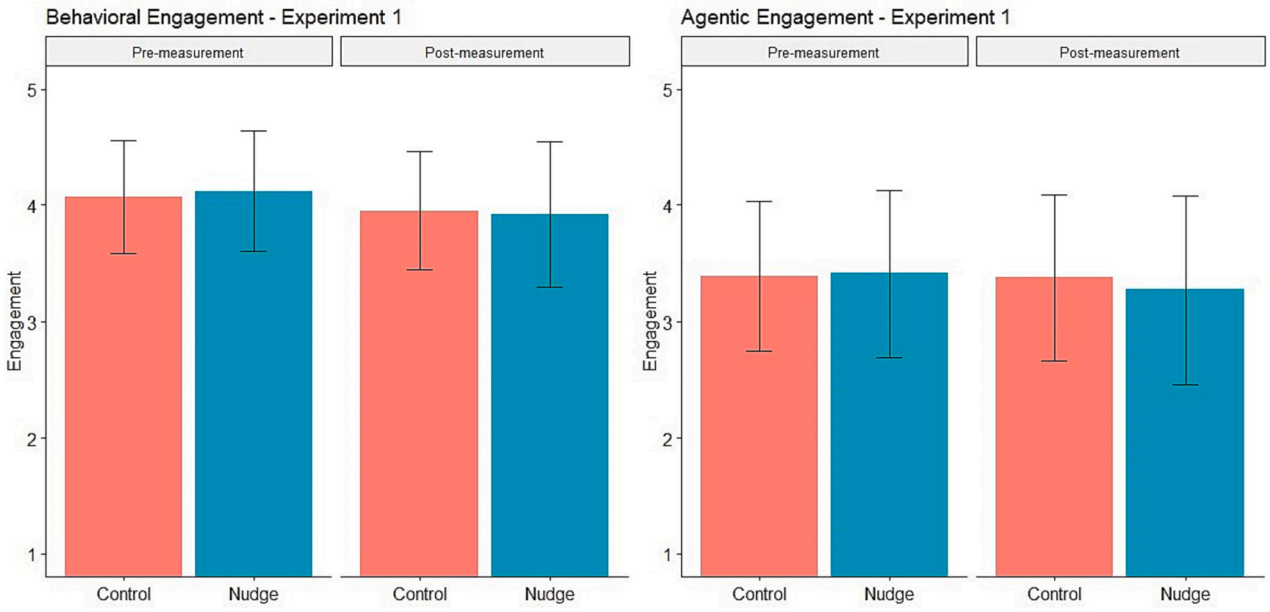

Fig. 3. Overview of Behavioral and Agentic Engagement Measures in Experiment 1.

7.1.4. Exploratory analyses

7.1.4.1. Extraversion. A priori, the students in the nudge condition ($M = 3.56$, $SD = 0.81$) were not significantly more (or less) extraverted ($p = .08$) than those in the control condition ($M = 3.70$, $SD = 0.77$). No direct effect of extraversion on the number of questions asked was found (*Estimate* = 0.05, $SE = 0.04$, $t(394.45) = 1.19$, $p = .24$), nor was there a significant interaction between extraversion and condition (*Estimate* = −0.03, $SE = 0.03$, $t(408.27) = -0.95$, $p = .34$). This means that more extravert students did not ask more (or less) questions during class than less extravert students, and that the effect of the nudge did not differ between more and less extravert students.

7.1.4.2. Self-reported question asking. Frequency statistics of this variable can be found in Table 4 & Fig. 4. The answer "4 or more" was converted to "4" to convert this variable into a numeric value for the analyses.

The average self-reported difficulty with asking questions was 3.28 ($SD = 1.14$). Self-reported question asking and self-reported difficulty with asking questions (mirrored) were moderately and significantly correlated ($r = 0.34$, $p < .001$). Self-reported question asking correlated weakly, but significantly, with the number of questions asked ($\rho = 0.16$, $p = .008$). Interestingly, no significant correlation was found between self-reported difficulty with asking questions and the number of questions asked ($r = 0.03$, $p = .64$). Students were greatly miscalibrated on how many questions they asked in class compared to how many questions were registered by the teacher: the estimated average was 1.30 ($SD = 0.92$) while they averaged 0.57 questions per lesson ($SD = 1.01$). Lastly, a moderate significant correlation was found between extraversion and reported difficulty with asking questions (mirrored) ($r = 0.38$ $p < .001$). A similar correlation existed for a student's extraversion and self-reported estimated number of questions ($r = 0.28$, $p < .001$).

Table 4
Self-Reported Estimation of Average Questions Per Lesson in Experiment 1.

Self-reported estimation of average questions per lesson	Number of students ($n = 253$)
0	48 (18.9%)
1	109 (43.1%)
2	70 (27.7%)
3	23 (9.1%)
4 or more	3 (1.2%)

7.2. Experiment 2 – Goal-setting nudge

7.2.1. Questions asked

The average student asked 0.63 questions per session ($SD = 1.13$). Students in the nudge condition ($M = 0.68$, $SD = 1.12$) did not ask significantly more questions per session(*Estimate* = −0.06, $SE = 0.08$, $t(16.57) = -0.81$, $p = .43$) than students in the control condition ($M = 0.58$, $SD = 1.15$). This result rejects Hypothesis 2a.

7.2.2. Engagement

The descriptive statistics of the engagement measures can be found in Table 5 and Fig. 5. No significant interaction was found between condition (control, nudge) and time (pre- and post-measure of self-reported behavioral engagement) (*Estimate* < 0.01, $SE = 0.02$, $t(68.90) = -0.07$, $p = .95$). This means that students in the nudge condition did not experience a different change in their behavioral engagement than students in the control condition, rejecting Hypothesis 2b. Similarly, no significant interaction was found between condition (control, nudge) and time (pre- and post-measure of self-reported agentic engagement) (*Estimate* < 0.01, $SE = 0.04$, $t(71.11) = 0.07$, $p = .94$). Therefore, Hypothesis 2c was rejected, meaning that students in the nudge condition did not experience a different change in their agentic engagement than students in the control condition.

7.2.3. Grades

The average student grade was 6.26 ($SD = 1.85$). Students in the nudge condition ($M = 6.29$, $SD = 1.91$) did not obtain significantly higher grades (*Estimate* = 0.03, SE = 0.14, $t(233) = 0.24$, $p = .81$) than students in the control condition ($M = 6.21$, $SD = 1.78$). This result rejects Hypothesis 2d. We found a statistical trend approaching significance of a direct effect of the average number of questions a student asked on their final grade (*Estimate* = 0.25, SE = 0.17, $t(233) = 1.96$, $p = .051$). This effect suggests – although it should be noted this effect is only a statistical trend - that students who ask more questions, obtain higher final grades.

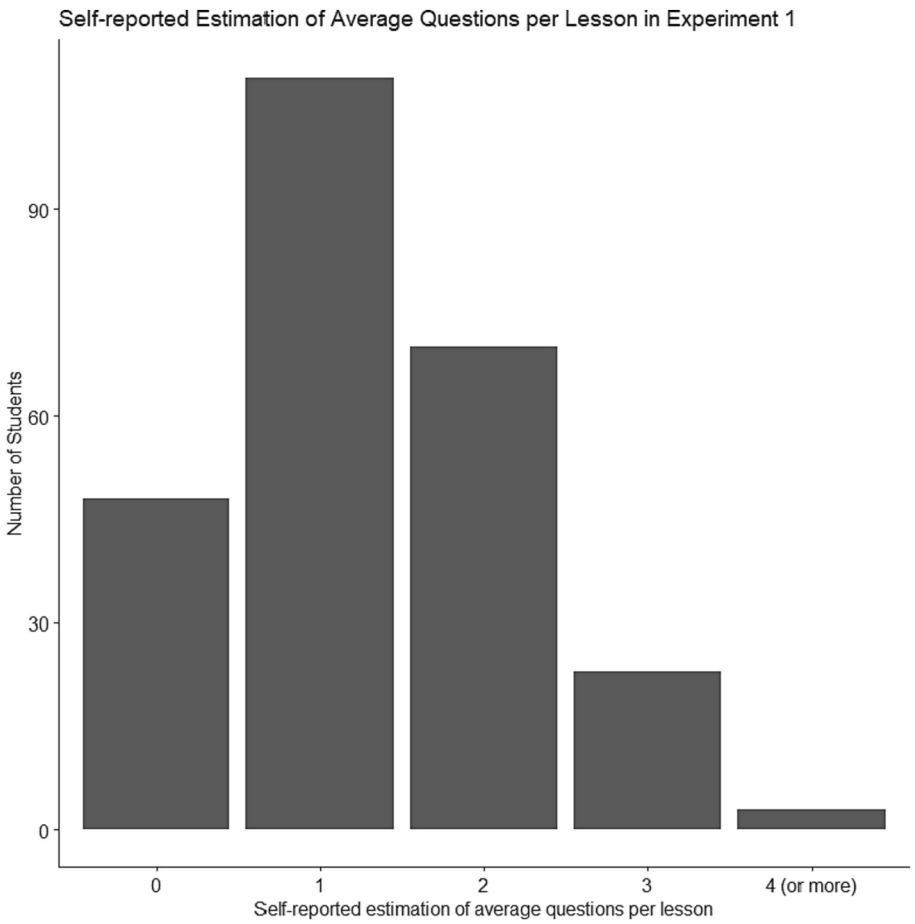

Fig. 4. Self-Reported Estimation of Average Questions Per Lesson in Experiment 1.

Table 5
Average and Standard Deviation of the Engagement Measures in Experiment 2.

	Pre-measurement	Post-measurement
Behavioral Engagement	4.03 (0.44)	3.93 (0.48)
control	3.91 (0.54)	3.81 (0.48)
nudge	4.11 (0.35)	4.02 (0.46)
Agentic Engagement	3.41 (0.62)	3.38 (0.68)
control	3.36 (0.58)	3.31 (0.74)
nudge	3.45 (0.65)	3.42 (0.64)

7.2.4. *Explorative analysis*

7.2.4.1. Extraversion. The students in the nudge condition ($M = 3.72$, $SD = 0.83$) were not a priori more extraverted ($t(183.8) = -1.02$, $p = .31$) than students in the control condition ($M = 3.61$, $SD = 0.82$). A significant direct effect of extraversion on the number of questions asked was found (*Estimate* = 0.16, $SE = 0.06$, $t(200.14) = 2.53$, $p = .01$). However, there was no significant interaction of the degree of extraversion on the effect of condition (*Estimate* = 0.12, $SE = 0.08$, $t(187.84) = -1.56$, $p = .12$). This means that the more extravert students asked more questions during class than the less extravert students, but the effect of the nudge did not differ between extravert and introvert students.

7.2.4.2. Self-reported question asking. Frequency statistics of this variable can be found in Table 6 and Fig. 6. The answer "4 or more" was converted to "4", for the purpose of the analyses.

The average self-reported difficulty with asking questions was 3.30 ($SD = 1.14$). Self-reported question asking and self-reported difficulty with asking questions (mirrored) were moderately and significantly correlated ($r = 0.35$, $p < .001$). Self-reported question asking was moderately and significantly correlated with the number of questions asked ($\rho = 0.35, p < .001$). A moderate significant correlation was found between self-reported difficulty with asking questions (mirrored) and the number of questions asked ($r = 0.27$, $p < .001$). Students were greatly miscalibrated on how many questions they asked in class: this subgroup's estimated average was 1.51 ($SD = 0.97$) questions per lesson while their actual average was 0.69 questions per lesson ($SD = 1.13$).

Lastly, a moderate significant correlation was found between extraversion and reported difficulty with asking questions. ($r = 0.37$ $p < .001$). A similar correlation existed for a student's extraversion and self-reported estimated number of questions ($r = 0.34$, $p < .001$).

8. Discussion

Online education is becoming more prevalent, but student participation during online classes is lower than during physical classroom teaching (Asgari et al., 2021; Lee & Choi, 2010). As student participation is important for student engagement (Chi & Wylie, 2014) and successful course completion (Appleton et al., 2008; Vayre & Vonthron, 2019), we tested a *prompt nudge* and a *goal-setting nudge* as potential tools for teachers to increase this participation, in the form of asking questions during class, and student agentic and behavioral engagement. While the previously found effectiveness of the goal-setting nudge was diminished in an online setting, we argue that the online context was well-suited for the *prompt nudge* to be effective. The teacher's virtual background was a prominent and permanent fixture on the students' screen - unlike a poster in a physical classroom environment, which can be easily missed or ignored, and unlike the set goal, which was only mentioned at the

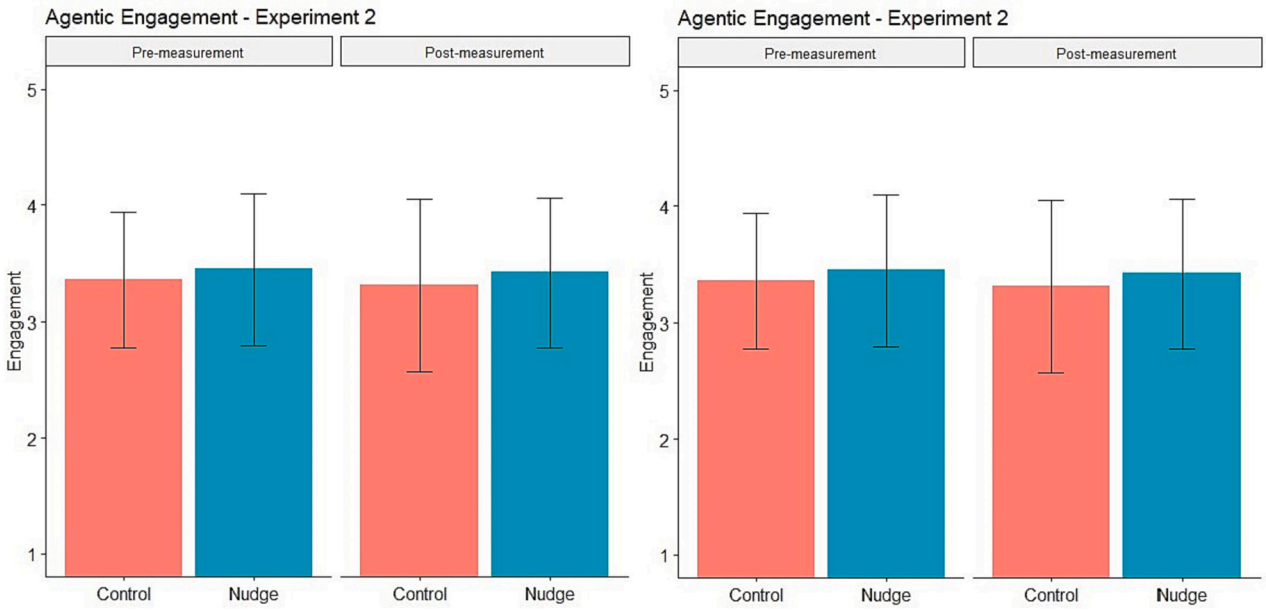

Fig. 5. Overview of Behavioral and Agentic Engagement Measures in Experiment 2.

Table 6
Self-reported Estimation of Average Questions per Lesson in Experiment 2.

Self-reported estimation of average questions per lesson	Number of students (n = 170)
0	22 (12.9%)
1	69 (40.5%)
2	58 (34.1%)
3	13 (7.6%)
4 (or more)	8 (4.7%)

start of the session.

When investigating the effect of the *prompt nudge*, we found a positive trend of the prompt nudge on the number of questions asked. It should, however, be noted that this trend disappeared when students who asked many questions were removed, demonstrating that this effect is likely based on a few active students being affected by the nudge instead of successfully nudging most students in a classroom. This finding was present over all three educational levels in tertiary education, making it a more generalizable effect. A possible explanation is that these different educational levels all received education in a very similar setting, namely online, and that only the content of the course meaningfully differed between them. However, the *prompt nudge* did not improve students' average grades. This means that this relatively simple intervention in the classroom had no follow-up effect on students' learning outcomes measured at a later moment. These findings indicate that the *prompt nudge* can be an easy tool in online classrooms to support immediate behavior in active students, as indicated by the increased number of asked questions, but with minimal effects on subsequent learning outcomes. Future studies could investigate whether this type of nudge could prompt students, active or otherwise, to specifically ask more in-depth questions and how that would affect the learning outcomes.

Exploratory analysis of the *prompt nudge* data revealed that the effect of the nudge on the number of questions asked was driven by students who were already asking the most questions. This means that the nudge does not promote all students to ask more questions, but rather encourages students who already ask the most questions to ask even more questions. This finding is similar to the Matthew effect (Merton, 1968) described in other educational contexts. This effect describes a finding that students who are already doing well compared to others benefit the most from an educational intervention, widening the gap between students. It should be considered whether this Matthew effect makes this nudge unusable for the online educational context, where students who are already struggling experience the negative consequences of online education disproportionally (Figlio, Rush, & Yin, 2013). Applying this nudge could further widen the gap between well-performing and struggling students.

Despite earlier promising findings (Weijers, de Koning, Vermetten, & Paas, 2023b), no effect of the *goal-setting nudge* was found. We can explain this difference by the context in which the nudge was implemented. In the previous study by Weijers, de Koning, Vermetten, and Paas (2023b), the *goal-setting nudge* was implemented in a physical classroom. In this type of classroom, the student-teacher connection is stronger than in online classrooms (Zohra et al., 2020), and the goal-setting can have been interpreted as a more personal and direct commitment compared to the same goal-setting in an online environment. From earlier research, it is known that goal-setting nudges are more successful when these aspects are present (e.g., Duckworth et al., 2013) but may fail without them (see Weijers, Ganushchak, Ouwehand, & de Koning, 2022, for an example of a failed commitment nudge in an online setting). Future research could investigate characteristics that enhance or limit the effect of goal setting nudges (also see Michie et al., 2014). If these characteristics are diminished by an online environment, this would confirm our explanation.

A possible explanation for the found difference in effect could be how the different nudges are assumed to work. The *prompt nudge* calls for self-generated questions to be actually asked in class. In contrast, the *goal-setting nudge* is a step before that, and encourages students to generate questions they otherwise would not have had. It is possible that a nudge was enough to push some active students over the proverbial hump to ask their question, but not to start the relatively intensive process of generating an appropriate question (reflecting on one's own knowledge and determining gaps, then formulating an appropriate question to fill the gap; Zimmerman, 2002). A nudge could be less suitable to trigger this effortful process, but more suitable to give the final push to ask the already generated question.

No effect of either nudge was found on either agentic or behavioral engagement. A possible explanation is that engagement is a more stable trait consisting of multiple behaviors, so improving one behavior in some students does not trigger a sizeable increase in overall engagement. This would indicate that the concept of spillover behaviors (Dolan

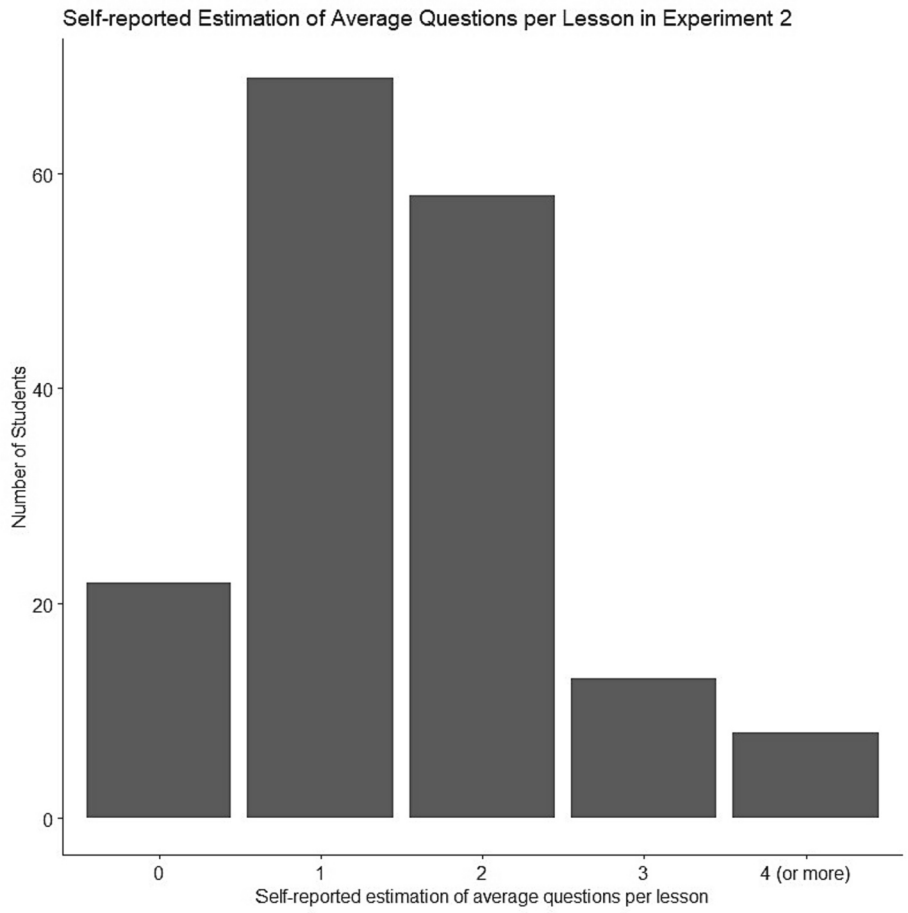

Fig. 6. Self-Reported Estimation of Average Questions Per Lesson in Experiment 2.

& Galizzi, 2015) is not visibly present here. A different explanation is that the self-report on the behavior does not fully correspond with the actual behavior, reaffirming the importance of using measures rooted in actual behavior (see also Ruggeri, 2019). Finally, students in both conditions in both experiments dropped in reported engagement before and after the course, which is possibly explained by course fatigue and initial optimism.

Exploratory analysis revealed that the trend effect of the prompt nudge is driven by students who ask the most questions. This corresponds with the findings of an earlier study (Weijers, de Koning, Vermetten, & Paas, 2023b), where a *goal nudge* also triggered more questions for students who already asked many questions. These findings indicate that an important determinant of the nudge's success in helping an individual is also linked to doing relatively well in school. Possible driving factors could therefore be academic motivation (Ryan & Connell, 1989), or a stronger perceived connection with the teacher (Konishi, Hymel, Zumbo, & Li, 2010). This last characteristic would also fit with the earlier mentioned conditions of effectiveness of a social nudge. Future research should investigate how nudges affect individuals and what characteristics are key in determining whether a nudge has an effect on an individual student. This can help when designing a nudge to promote asking questions for the students who do not ask many questions, or ask no questions at all.

Exploratory analysis also reaffirmed the importance of question asking during class. Students who asked more questions achieved higher final grades in Experiment 1, and we had a similar finding– although this finding was only approaching significance - in Experiment 2. This indicates that asking more questions could be a possible predictor for student success. However, it should be noted that it is unclear whether this is relationship is causal, or that this finding is driven by an underlying factor like high academic motivation (Ryan & Connell, 1989) that could lead to both higher grades and asking more questions. Surprisingly, we found no robust effect of extraversion on question asking, despite it being linked to passiveness (Offir et al., 2007) and preference of anonymity in class (Latham & Hill, 2014). However, the lack of effect of extraversion on questions can be tied to the found lack of effect of student engagement on questions, as extraversion is tied to student engagement (Quigley et al., 2022; Sawang et al., 2017). This finding also corresponds with an earlier finding on extraversion not being linked to a student's preferred teaching method (e.g., listening to the lecture vs. engaging in classroom discussion; Murphy, Eduljee, Croteau, & Parkman, 2017). We did find evidence for miscalibration (Hattie, 2013) even for the very specific, accessible behavior of asking questions during class: students strongly overestimated their own behavior. As this information is too optimistic (i.e, students think they are asking more questions than they actually are), this cue may lead them to misjudge their learning process (Baars et al., 2020; Van Laer & Elen, 2019). It is possible that the reason why this very specific behavior is also misrepresented is that students were not honest and wanted to present themselves as more active students than they were, Alternatively, they actually saw themselves as more active than they were, as a consequence of a self-serving bias (Mezulis, Abramson, Hyde, & Hankin, 2004).

Even though our initial findings when investigating the effectiveness of possible interventions in this area have been minimal, future research can focus on improving asking questions directly. When doing so, it should be considered that the prompt nudge provides a call to action for students who have questions but are not asking them. The nudge does not prompt students to generate extra questions, only to ask the questions when they have them. It is possible that students who do not ask more questions do not know how to formulate a helpful question,

experience behavioral barriers that are not addressed by this nudge, or simply do not have questions to ask. Future research could explore how these students can be helped – with or without a nudge.

9. Limitations

This study is subject to several limitations. The first set of limitations relates to aspects of the nudges. First, the longevity aspect of the nudge was not investigated, although creating a long-term impact is one of the main challenges of nudging (Marchiori, Adriaanse, & De Ridder, 2017) and many nudges are not effective in the long term (Raymaekers, Fobé, & Brans, 2018). Future research could investigate whether the effect of the *prompt nudge* intervention persists over time. Another aspect is the content of the nudge. The nudges investigated in this study were aimed at increasing a specific behavior, asking questions, at a rather general level where the same nudge was implemented across classes. Future research may focus on testing this nudge in courses with the same context, possibly changing the content of the nudge to be geared towards the learning goals of the specific course or even session.

The second set of limitations relates to measurement issues. The broader concept of student engagement was measured only using self-report (behavioral and agentic engagement), instead of an objective behavioral measure. Given the earlier stressed importance of using behavioral measurements, this makes conclusions about the nudge in relation to student engagement perhaps premature. Also, the questions were quantified and reduced to a count in this study, and not analyzed based on their content. Future research could analyze prompted questions in a qualitative way to see how they fit within the students' learning process. Building on this, following the intervention with a qualitative setup, e.g., conducting interviews or focus groups with students, could reveal why the nudge intervention did or did not work for them. For the measurement of learning outcomes, grades were compared across different classes and different course content, making them more general indicators of student achievement than of specific course content learned through asking questions. A general grade may have been a suboptimal measure for comparing students' attainment of learning goals, especially across different educational levels and fields, and any results should be interpreted with caution. Future research could focus on classes with the same content so learning outcomes could be further explored using the same exam for all students or even explore this on a deeper level, addressing how the nudge affects different levels of learning (e.g., retention and transfer; Allen, Robbins, Casillas, & Oh, 2008). However, it should be noted that we found no effects of the nudge on grades in this study, and therefore do not necessarily expect to find an effect of the nudge on different measures of learning outcomes.

The third set of limitations relates to methodological issues. Despite controlling for several relevant factors in the randomization, there may be other factors that confound the results given the sample size of a very diverse group of teachers and students (e.g., the time students spent in direct contact with the teacher during class as opposed to working in individual online workspace like "breakout rooms"). Future studies could reduce such confounding factors by examining the prompt nudge in contexts that are more similar, for instance in a course with many classes following the same structure, or follow a stricter protocol to control the quality of randomization. Lastly, a possible explanation for the found nudging effect is that the teachers were not blind to their conditions, creating a situation in which they – consciously or subconsciously – might have favored the students in the experimental conditions (e.g., by adapting a more favorable teaching style for these classes). We find this explanation not very likely, as we would expect to find a similar effect for the *goal-setting nudge* if this were the case.

10. Practical recommendations

The prompt nudge is a potentially useful tool for teachers to apply within their online classroom, given its effect on questions asked and the minimal effort with which it can be implemented across different levels of tertiary education. There are some points to consider for teachers looking to implement this intervention. First, the context of the session should be considered: is this a lesson that can be enhanced by students asking questions? For example, in a lesson where questions asked by students can generate additional debate or conversations to deepen understanding of a complex topic? Using the nudge only at specific times, also known as the "just-in-time" approach (e.g., Hardeman, Houghton, Lane, Jones, & Naughton, 2019), may be more effective than using it as a blanket approach. Second, the prompt should be inviting, ideally coherent with the institution's style, but not too distracting, as that could interfere with the cognitive load students are already experiencing (Weijers, de Koning, & Paas, 2021) which could diminish students' learning. Lastly, the readability and visibility of the prompt should be considered, especially when also sharing a presentation (as the teacher might minimize or even disappear), or when students are likely to use a smaller phone screen to watch a lecture. The results of the study show that the nudge on its own is not sufficient to stimulate question asking behavior in online classrooms, and no effects were found on student engagement or learning outcomes. This indicates that, while teachers can use the prompt-nudge as an easy and cheap addition to their learning environment, promoting asking questions in an online environment requires more tools for the teacher to implement.

11. Conclusion

The findings demonstrate that the *prompt nudge* is a possible additional tool for teachers looking to increase student participation in online settings. The ease of implementation of the *prompt nudge* across the three different educational levels emphasizes the nudge's applicability as a teaching tool for tertiary education in an online context, even though the effect is small and likely limited to students who already ask many questions. Although in earlier research the *goal-setting nudge* appeared to be a useful tool in an offline context, it seems less effective in an online context. Another conclusion that can be tentatively drawn is that learner characteristics like question asking behavior and possibly extraversion influence nudging effectiveness and the number of questions asked respectively. For teachers, this means that they have to adapt their teaching, supplemented with nudges, to the needs of different learners. Finally, nudge effects are specific as they did not spill over to "adjacent" behavior (e.g., behavioral and agentic engagement), reaffirming that it is important to keep in mind what you aim to achieve with a nudge. With this, the present study contributes to the emerging field of studying nudging in education (Weijers, de Koning, & Paas, 2021) and provides an impetus for future studies to explore nudging in different contexts and identify driving factors, like student characteristics, that might influence the effectiveness of the nudge.

Declaration of Competing Interest

None.

Data availability

Data can be found on the Open Science Framework: https://osf.io/hmujz/?view_only=bc766f6b2b1c46faae2a6ae5a1da9409

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iheduc.2023.100931.

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