



# The effects of achievement goal instructions in game-based learning on students' achievement goals, performance, and achievement emotions

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## ABSTRACT

**Background:** Achievement goal instructions are instructions that assign the learners' achievement goals beforehand, such as mastery-approach goal instructions that emphasize "to learn as much as possible" and performance-approach goal instructions that emphasize "to be the best player". Achievement goal instructions can induce specific goals in learning, but it is unclear which achievement goal instruction is best for motivation, cognition, and emotion in game-based learning.

**Aims:** The purpose of this paper is to investigate 1) how achievement goal instructions affect motivation (i.e., achievement goals), cognition (i.e., mental effort and performance), and emotion (i.e., achievement emotions) in chemistry game-based learning and 2) whether prior achievement goals moderate the effects of achievement goal instructions.

**Sample:** Participants were secondary school students ( $N = 450$ ).

**Methods:** In a  $2 \times 2$  factorial design with the factors mastery-approach goal instructions (yes, no) and performance-approach goals (yes, no), participants were randomly assigned to one of the four conditions: mastery-approach goal instructions condition, performance-approach goal instructions condition, combined mastery-approach and performance-approach goal instructions condition, and control condition.

**Results:** Robust regression analysis revealed that mastery-approach goal instructions and performance-approach goal instructions did not interact. Mastery-approach goal instructions had no effects on mastery-approach goals. Performance-approach goal instructions promoted higher performance-approach goals and higher mental effort but lower posttest performance. Prior mastery-approach goals moderated the effects of achievement goal instructions on mental effort.

**Conclusions:** We conclude that achievement goal instructions in game-based learning affect cognitive and motivational outcomes differently. Educators would do well to consider achievement goal instructions and learners' prior mastery-approach goals.

## 1. Introduction

Stakeholders, in particular educators, expect that game-based learning (GBL) is effective (i.e., facilitating cognitive processes and outcomes), motivating (i.e., facilitating motivational processes and outcomes), and enjoyable (i.e., facilitating emotional processes and outcomes; see Hu et al., 2021 for an overview). GBL needs effective instructional design features to achieve this (Plass et al., 2020). In this study, we focus on the instructional design feature: *goal instructions* - instructions that assign the learners' specific goals beforehand (Erhel & Jamet, 2016). Practically, compared with other instructional design

features, goal instructions can be easily implemented in GBL. Theoretically, goal instructions may affect at least the cognitive aspects, such as cognitive load, in learning (Hawllitschek & Joeckel, 2017). Empirically, previous studies have shown that goal instructions can induce specific goals. However, the results of goal instructions on cognitive processes and outcomes are inconsistent, and research on the effects on motivation or emotion is sparse or even lacking (Erhel & Jamet, 2013, 2016, 2019; Hawllitschek & Joeckel, 2017; Miller et al., 1999; Nebel et al., 2017; Vandercruysse et al., 2015).

This study investigates how achievement goal instructions affect motivational, cognitive, and emotional processes and outcomes in

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chemistry GBL and whether prior achievement goals moderate the effects of achievement goal instructions. *Achievement goals* are goals that relates to competence-relevant behavior inside or outside of achievement settings (Elliot & Hulleman, 2017). They can be categorized into two types: *Mastery-approach goals* that emphasize mastery and *performance-approach goals* that emphasize outperformance. It is known that achievement goals influence GBL (Plass et al., 2020). Furthermore, researchers from the multiple goal perspective (Barron & Harackiewicz, 2001) have suggested that *multiple goals* - a combination of mastery-approach goals and performance-approach goals - have optimal outcomes, which may be explained by four mechanisms: 1) mastery-approach goals and performance-approach goals affect different outcomes (*specialized mechanism*); 2) mastery-approach goals and performance-approach goals affect the same outcome (*additive mechanism*); 3) the most relevant goal in a given context produces an effect (*selective mechanism*); or 4) mastery-approach goals and performance-approach goals interact (*interactive mechanism*). However, research on achievement goal instructions is lacking (Elliot & Hulleman, 2017) and the interactive mechanism of multiple goal perspective has not been tested.

In addition, the effects of achievement goal instructions may depend on *prior achievement goals* - achievement goals that are set prior to learning (Niemivirta, 2002). When students enter learning settings with different prior achievement goals, prior achievement goals may interact with achievement goal instructions (Murayama & Elliot, 2009). However, it is yet unclear whether prior achievement goals moderate the effects of achievement goal instructions (*moderation effect*).

So, the major theoretical contribution of this study will be insight in the effect of achievement goal instructions on not only cognition but also motivation and emotion, and the role therein of prior achievement goals. The major practical contribution is to guide the practitioners, such as educators and game designers, to induce achievement goals that promote motivating, effective, and enjoyable learning experiences in educational settings, such as GBL, and consider learners' individual characteristics, such as prior achievement goals.

### 1.1. Theoretical background and empirical research

We assume that achievement goal instructions influence GBL in three ways: by affecting motivational processes, by affecting cognitive processes, and/or by affecting emotional processes (see Hu et al., 2024 for a detailed theoretical framework). This study focuses on achievement-relevant theories, namely, achievement goal theory (AGT; Elliot & Hulleman, 2017), cognitive load theory (CLT; Sweller et al., 2019), and control-value theory of achievement emotions (CVT; Pekrun & Linnenbrink-Garcia, 2014) to substantiate this assumption. These theories and their constructs are chosen because of their critical role when assessing motivation, cognition, and emotion in complex learning, such as GBL (Loderer et al., 2020; Plass et al., 2020). Fig. 1 illustrates the theoretical propositions.

#### 1.1.1. Achievement goal instructions and achievement goals

From a motivational perspective, achievement goal instructions may promote *achievement goals* (i.e., achievement goals that are induced by achievement goal instructions, Noordzij et al., 2021). Achievement goal instructions are examples of *achievement goals interventions* - interventions that aim to manipulate achievement goals. According to AGT (Elliot & Hulleman, 2017), *achievement goals* indicate whether one is doing poorly or well, relative to the demands of a task (task-based), past performance or future potential (self-based or intrapersonal), and/or others (other-based or normative). The  $2 \times 2$  achievement goal model (Elliot & Murayama, 2008) introduces four categories of achievement goals: 1) *mastery-approach goals*: striving for task-based or self-based competence, 2) *mastery-avoidance goals*: avoiding task-based or self-based incompetence, 3) *performance-approach goals*: striving for other-based competence, and 4) *performance-avoidance goals*: avoiding

other-based incompetence. This study focuses only on state-based approach goals, considering that approach goals are more beneficial for learning than avoidance goals (see 1.1.2 and 1.1.3 for more elaboration) and avoidance goals, especially mastery-avoidance goals, may not be as prevalent as other achievement goals among secondary school students as theory expected (see e.g., Bong, 2009; Strunk et al., 2020).<sup>1</sup>

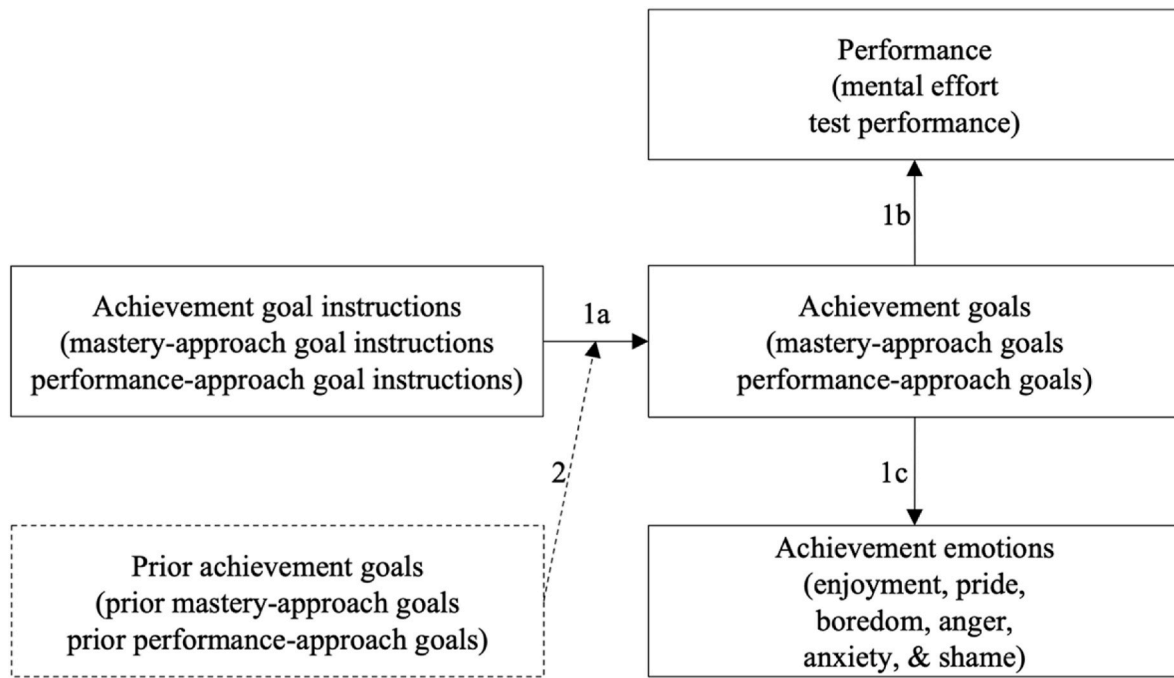
According to AGT, mastery-approach goal instructions that emphasize mastery, understanding, and improvement may mostly induce mastery-approach goals and performance-approach goal instructions that emphasize competition may mostly induce performance-approach goals (Fig. 1 line 1a). Hence, we expect the specialized mechanism (i.e., mastery-approach goal instructions and performance-approach goal instructions affect different outcomes, that is, mastery-approach goals and performance-approach goals, respectively) of the multiple goal perspective for achievement goals: Students who receive mastery-approach goal instructions (i.e., including mastery-approach goal instructions condition and multiple goal instructions condition) report higher mastery-approach goals than those who do not receive mastery-approach goal instructions (i.e., including control condition and performance-approach goal instructions condition); and students who receive performance-approach goal instructions (i.e., including performance-approach goal instructions condition and multiple goal instructions condition) report higher performance-approach goals than those who do not receive performance-approach goal instructions (i.e., including control condition and mastery-approach goal instructions condition). Statistical support for these expectations would be main effects of mastery-approach goal instructions on mastery-approach goals and main effects of performance-approach goal instructions on performance-approach goals. If this is the case, educators can use achievement goal instructions to induce achievement goals in GBL.

Empirically, however, it is unclear whether achievement goal interventions work based on the results of two similar studies with four conditions (i.e., control condition, mastery-approach goal condition, performance-approach goal condition, multiple goal condition): Achievement goal interventions worked for both mastery-approach goals and performance-approach goals (Pahljina-Reinić & Kolić-Vehovec, 2017) or only for performance-approach goals (Muis et al., 2013).

#### 1.1.2. Achievement goals, mental effort, and performance

From a cognitive perspective, achievement goal instructions may affect cognitive load and performance via achievement goals (Fig. 1 coupling of line 1a and 1b; Murayama & Elliot, 2009). According to the updated CLT (Sweller et al., 2019), three types of cognitive load can be defined: 1) *intrinsic load* - the load caused by processing task-relevant information; the more complex this information the higher the intrinsic cognitive load and the more knowledgeable the learner the lower the intrinsic cognitive load; 2) *extraneous load* - the load caused by cognitive processes or activities that are unnecessary for learning and performing the task; for example, searching for task-relevant information because of ill-structured text or ill-designed diagrams; and 3) *germane load* - the load caused by cognitive processes or activities that are relevant for learning and performing the task; for example, distinguishing main and side points in task-relevant information. The overall cognitive load - intrinsic load plus extraneous load - varies and can be estimated by the amount of mental effort that learners exert in a task (Sweller et al., 2019). Germane load arises when mental effort is invested in learning from task-relevant information on top of merely processing it (intrinsic load) instead of investing effort in processes irrelevant for learning (extraneous load). So, germane load does not add to the overall cognitive load but redistributes the mental effort

<sup>1</sup> Avoidance goals were measured but not reported because they are not as prevalent as other achievement goals among secondary school students (see e.g., Bong, 2009; Strunk et al., 2020).



**Fig. 1.** Overview of the relations between achievement goal instructions, achievement goals, performance, achievement emotions, and prior achievement goals. Note. Rectangles represent independent and dependent variables; Arrows represent causal relations; Dotted rectangles represent moderators; Dotted arrows represent moderation. To reduce the complexity, the direct effects of covariates including prior achievement goals and pretest performance are not shown but are tested.

investment from extraneous to intrinsic task aspects. Given the methodological weakness of measuring intrinsic load and extraneous load separately (Kriegelstein et al., 2022), this study focuses on mental effort as the indicator of overall cognitive load.

Although research that investigates the relation between achievement goal instructions and mental effort is sparse, we propose that mastery-approach goals and performance-approach goals may increase mental effort, relative to no goals. Especially, mastery-approach goals that focus on learning and improving, are likely to stimulate learners to invest more mental effort in the learning process (i.e., intrinsic and germane load). In addition, performance-approach goals focus on outperforming, and learners are likely to invest more mental effort on, for instance, winning (i.e., extraneous load). Thus, mastery-approach goals and performance-approach goals have a similar effect on invested mental effort albeit through different mechanisms. However, investing more mental effort does not necessarily mean higher performance due to the different sources of cognitive load: Relative to no goals, higher mental effort may come from intrinsic and germane load for mastery-approach goals and from extraneous load for performance-approach goals.

Regarding the relation between achievement goals and performance, AGT proposes that mastery-approach goals and performance-approach goals focus on success and promote task engagement and performance, relative to no goals (Elliot & Hulleman, 2017). However, previous meta-analyses on achievement goals found that mastery-approach goals generally lead to higher performance than no goals, whereas performance-approach goals do not lead to higher performance than no goals (Noordzij et al., 2021; Utman, 1997; van Yperen et al., 2015). An example of the achievement goal instructions of the studies included in the meta-analysis is “the purpose of this session was to teach you a new way of doing math, to adopt a learning goal as you go through the session, and to focus on how well the new techniques can help you develop and improve your math skills” (mastery-approach goal instructions) and “the purpose of the session is to evaluate how well you could perform match problem using a new way of doing match, to adopt a performance goal as you go through the session, and to focus on how well the techniques can help you perform and solve more math problems

than other students” (performance-approach goal instructions; Barron & Harackiewicz, 2001).

Therefore, we expect the additive mechanism (i.e., mastery-approach goal instructions and performance-approach goal instructions affect the same outcome, that is, mental effort and performance) and interactive mechanism (i.e., mastery-approach goal instructions and performance-approach goal instructions interact) of the multiple goal perspective for mental effort and posttest performance: Students who receive mastery-approach goal instructions report higher mental effort and posttest performance, than those who do not receive mastery-approach goal instructions; students who receive performance-approach goal instructions report higher mental effort and lower posttest performance than those who do not receive performance-approach goal instructions; and students who receive mastery-approach goal instructions report higher posttest performance when they also receive performance-approach goal instructions than when they do not receive performance-approach goal instructions, while students who do not receive mastery-approach goal instructions report higher posttest performance when they do not receive performance-approach goal instructions than when they also receive performance-approach goal instructions (Fig. 1 line 1b). Statistical support for these expectations would be main effects of mastery-approach goal instructions and performance-approach goal instructions on mental effort and posttest performance, and mastery-approach goal instructions  $\times$  performance-approach goal instructions interaction effects on posttest performance.<sup>2</sup>

### 1.1.3. Achievement goals and achievement emotions

From an emotional perspective, achievement goal instructions may affect achievement emotions via achievement goals (e.g., Pekrun et al., 2006, 2009; Pekrun et al., 2014, Fig. 1 coupling of line 1a and 1c). According to CVT (Pekrun & Linnenbrink-Garcia, 2014), achievement emotions are emotions that relate to competence-relevant activities (e.g.,

<sup>2</sup> Game performance should be measured by time-on-task (start time of the posttest – end time of the pretest) from the log data. Due to technical issues, we could not use log data and thus game performance was not reported.

attending class) and/or outcomes (i.e., success or failure) in achievement settings. Depending on the object of emotions, achievement emotions can be distinguished as *activity emotions* associated with achievement-relevant activities or tasks, such as enjoyment, boredom, and anger, and *outcome emotions* associated with the outcomes of those activities, such as pride, hope, anxiety, shame, and anger. Combined with the valence of emotions (positive or negative), achievement emotions can be categorized into four categories: 1) *positive activity emotions*, such as enjoyment; 2) *negative activity emotions*, such as boredom and anger; 3) *positive outcome emotions* related to success, such as hope and pride; and 4) *negative outcome emotions* related to failure, such as anxiety and shame. Achievement emotions can help or harm learning (Pekrun & Linnenbrink-Garcia, 2014), so the goal of instructional design in GBL is to induce achievement emotions that help learning. This study focuses on learning-related emotions, including enjoyment, pride, anger, anxiety, boredom, and shame, as these emotions are typical in GBL (Loderer et al., 2020).

The relations between achievement goals and achievement emotions may depend on the type of achievement goals (mastery goals or performance goals) and the type of achievement emotions (activity emotions or outcome emotions). Theoretically, mastery-approach goals may focus students' attention on the activity itself and thereby influence activity emotions, such as enjoyment or boredom, whereas performance-approach goals may focus students' attention on the outcomes and thereby influence outcome emotions, such as pride or shame (Pekrun et al., 2014). Empirically, these links between mastery goals and activity emotions and between performance goals and outcome emotions have been supported by studies on achievement goal interventions (e.g., mastery-approach goals feedback or performance-approach goals feedback; Pekrun et al., 2014). In addition, a meta-analysis on personal achievement goals (Huang, 2011) suggested that mastery-approach goals and performance-approach goals are mostly positively associated with positive emotions and negatively associated with negative emotions.

As such, we expect the specialized mechanism (i.e., mastery-approach goal instructions and performance-approach goal instructions affect different outcomes, that is, activity emotions and outcome emotions, respectively) of the multiple goal perspective for achievement emotions: Students who receive mastery-approach goal instructions report more positive activity emotions and less negative activity emotions than those who do not receive mastery-approach goal instructions; and students who receive performance-approach goal instructions report more positive outcome emotions and less negative outcome emotions than those who do not receive performance-approach goal instructions (Fig. 1 line 1c). Statistical support for these expectations would be main effects of mastery-approach goal instructions on activity emotions and main effects of performance-approach goal instructions on outcome emotions.

#### 1.1.4. Moderation effect of prior achievement goals on the effect of achievement goal instructions

Prior achievement goals may function as moderators if they either strengthen or weaken the effects of achievement goal instructions on achievement goals (Fig. 1 line 2). According to research on person-environment interactions, learning processes and outcomes are expected to be optimal when the characteristics of the person are congruent with those of the social environment (Eccles et al., 1993). Specifically, we expect that achievement goal instructions may interact with the characteristic of the person, such as prior achievement goals (Murayama & Elliot, 2009).

According to the *match hypothesis* (Murayama & Elliot, 2009), achievement goal instructions may have optimal effects on learning processes and outcomes when they match prior achievement goals. For example, mastery-approach goal instructions may have stronger effects on achievement goals, mental effort, performance, and achievement emotions when learners hold higher than lower prior mastery-approach

goals, and performance-approach goal instructions may have stronger effects on achievement goals, mental effort, performance, and achievement emotions when learners hold higher than lower prior performance-approach goals.

According to the *mismatch hypothesis* (Murayama & Elliot, 2009), if achievement goal instructions mismatch prior achievement goals, the effects of achievement goal instructions may be *vibrated*, that is, a beneficial effect is weakened, *migrated*, that is, a detrimental effect is weakened, or *exacerbated*, that is, a detrimental effect is strengthened. For example, mastery-approach goal instructions may have weaker positive effects when learners hold higher than lower prior performance-approach goals; and performance-approach goal instructions may have weaker positive effects when learners hold higher than lower prior mastery-approach goals (a vibration effect).

Empirically, evidence from seven previous studies is inconclusive. Five studies supported the match hypothesis, but only for some learning processes and outcomes (e.g., effort) and not for others (e.g., course grade) and only one out of four studies supported the mismatch hypothesis: A positive correlation between performance-approach goals and intrinsic motivation is vibrated by mastery goal structures (Hofverberg & Winberg, 2020; Lau & Nie, 2008; Linnenbrink, 2005; Muis et al., 2013; Murayama & Elliot, 2009; Wolters et al., 2004). In addition, five studies were non-experimental and only two manipulated achievement goals (Linnenbrink, 2005; Muis et al., 2013). As such, we expect that prior achievement goals moderate the effects of achievement goal instructions. If this is the case, educators would do well to consider students' prior achievement goals.

#### 1.2. Present study

This study investigates how mastery-approach goal instructions and performance-approach goal instructions affect motivation (i.e., achievement goals), cognition (i.e., mental effort and performance), and emotion (i.e., achievement emotions) in chemistry GBL (RQ1) and whether prior achievement goals moderate the effects (RQ2). Based on the specialized mechanism, additive mechanism, and interactive mechanism of the multiple goal perspective and the match and mismatch hypothesis, we formulate the hypotheses as follows:

**RQ1 (Main effects and interaction effects):** There are positive main effects of mastery-approach goal instructions on mastery-approach goals, mental effort, posttest performance and positive activity emotions (enjoyment) and negative main effects on negative activity emotions (anger, boredom).

There are positive main effects of performance-approach goal instructions on performance-approach goals, mental effort, and positive outcome emotions (pride) and negative main effects on posttest performance and negative outcome emotions (anxiety, shame).

There are interaction effects between mastery-approach goal instructions and performance-approach goal instructions on posttest performance.

**RQ2 (Moderation):** The higher the prior mastery-approach goals or the lower the prior performance-approach goals, the higher the effects of mastery-approach goal instructions on mastery-approach goals, mental effort, performance, and achievement emotions.

The higher the prior performance-approach goals or the lower the prior mastery-approach goals, the higher the effects of performance-approach goal instructions on performance-approach goals, mental effort, performance, and achievement emotions.



## 2. Method

### 2.1. Participants

Based on a prior power analysis in G\*power 3.1 (Faul et al., 2007), our minimum sample size was 279 with F tests - Linear multiple regression, effect size  $f^2 = 0.0625$ ,  $\alpha = 0.05$ , power = 0.80, and number of predictors = 11 (two from independent variables, two from covariates, two from moderators, one interaction from two independent variables, four interactions from two independent variables and two moderators). We approached chemistry teachers from 113 secondary schools in the Netherlands. Seven chemistry teachers from seven schools were interested in participating with at least one class. A total of 583 students from nine schools participated. At the end of the experiment, each student received a pack of snacks, and each teacher received a 25 euros voucher. We excluded 133 participants who played the wrong game levels and/or who did not finish the game due to time constraints or other obligations, such as other appointments. Thus, the missing data were unrelated to any of the study variables. In total, 450 participants were included (243 male, 201 female, 6 neutral, age range = 13–18,  $M = 15.1$  years,  $SD = 1.1$ ).

### 2.2. Design

Because the present study focused on the main effects of mastery-approach goal instructions, main effects of performance-approach goal instructions, and their interaction effects, the design a  $2 \times 2$  factorial design with two factors: mastery-approach goal instructions (yes or no) and performance-approach goal instructions (yes or no). We randomly assigned all participants to one of the four conditions: 1) mastery-approach goal instructions condition ( $n = 110$ ); 2) performance-approach goal instructions condition ( $n = 111$ ); 3) multiple goal instructions condition ( $n = 112$ ); and 4) no goal instructions condition ( $n = 117$ ).

### 2.3. Materials and measures

The materials and measures, except for the achievement goal instructions, were based on two previous studies (Hu, Elliot et al., 2024; Hu, Wouters et al., 2024). All the materials and measures were in Dutch.

#### 2.3.1. Achievement goal instructions

Three achievement goal instructions were created. The *mastery-approach goal instruction* emphasized mastery and learning: “When you play the game, try to master the chemistry content. For example, when you are in the game level of the sieve, try to learn what is a sieve, when and how to use a sieve. The goal is to learn as much as possible.”. The *performance-approach goal instruction* emphasized outperformance and winning: “When you play the game, try to be the first to finish the game. For example, when you are in the game level of the sieve, try to finish the level as fast as possible. The goal is to be the best player.”. The *multiple-goal instruction* emphasized mastery, learning, outperformance, and winning: “When you play the game, try to master the chemistry content and to be the first to finish the game. For example, when you are in the game level of the sieve, try to learn what is a sieve, when and how to use a sieve, and to finish the level as fast as possible. The goal is to learn as much as possible and to be the best player.”. The *no goal instructions* received no goal instructions. All groups received the same general introduction: “In the next hour, you will play a chemistry game and explore separation techniques to recycle materials. In the game, you will complete 11 game levels (1, 2, 3, 7, 13, 19, 22, 24, 26, 29, and 32) that introduce you to 9 processors, such as a sieve, a melter, a magnet, a shredder, a non-ferrous separator, a stream separator, a boiler, a dissolver, and a centrifuge.”.

The mastery-approach goal instructions focused on task-based goals instead of self-based goals as it was difficult to ask participants to adopt self-based goals in our GBL environment, and thus task-based goals were

more relevant than self-based goals. These instructions were written as texts on Gorilla (<https://app.gorilla.sc>). Participants received these instructions after the pretest but before the gameplay. Participants who finished the study were required to leave and other participants could see who finished and who did not. Participants knew beforehand that there was a posttest, and they were free to leave when done.

Before the achievement goal instructions, participants got a note: “Pay attention: In a moment you will receive instructions for playing game. Read this instruction carefully! After reading, you will get one question about the instruction.” The no goal instructions group got a general note: “Pay attention: In a moment you will receive instructions for playing game. Read this instruction carefully!”. Immediately after the achievement goal instructions, participants were asked to choose “Yes” or “No” to one of the following questions: “Based on the previous instructions, should you play the game to learn as much as possible? (Mastery-approach goal instructions)”; “Based on the previous instructions, should you play the game to be the best player? (Performance-approach goal instructions)”; or “Based on the previous instructions, should you play the game to learn as much as possible and be the best player?” (Multiple goal instructions). The no goal instructions group received no questions. If the participant chose “No”, they were asked to read the achievement goal instructions again and answer this question again. This note and question were used as a reminder to ensure that participants read and understood the achievement goal instructions. After this question but before gameplay, we again showed participants the correct answer to reconfirm the manipulated achievement goals.

#### 2.3.2. The game – CosmiClean

CosmiClean ([recyclegame.eu](http://recyclegame.eu)) was designed by LuGus Studios ([www.lugus-studios.be](http://www.lugus-studios.be)) to teach secondary school and university students the principles for separation processes of recycling materials. The chemistry learning content included the functions of the nine separators (including the sieve, the melter, the magnet, the shredder, the non-ferrous separator, the stream separator, the boiler, the dissolver, and the centrifuge) and the eight properties (including size, density, phase, melting point, boiling point, solubility, magnetic metal, and non-ferrous metal) of 12 materials (including iron, plastics, concrete, wood, glass, sand, copper, water, salt, fuel, gold, and solvent). Players completed a series of game levels with different mixtures of materials in a spaceship cargo. The goal was to make a recycling chain, including a conveyor (for transporting the materials), one or more separators (for separating material based on different properties), and receptors (for collecting the recycled materials).

Participants completed the 11 game levels individually and once. Levels 1 and 2 were preinstalled with receptors. Level 3 was the first complete task in which players are required to build a complete recycling chain. From level 3 onwards, each level introduced a new separator, and a higher level did not necessarily have to be any more challenging than lower levels. Participants were asked to play from low to high levels and could not skip levels.

#### 2.3.3. Knowledge test

The pre- and post-knowledge test included the same test items, but in a different order. The knowledge test assesses Remember (5 multiple-choice questions), Apply (7 multiple-choice questions), and Evaluate (3 open-ended questions) levels based on the Bloom taxonomy (Anderson & Krathwohl, 2001). Each multiple-choice question had three alternatives. For example, a Remember question was: “Which property is used by stream separator?”. An Apply question was: “Gold is not dissolvable. Which processor can be used to separate copper and gold from their mixture?”. An Evaluate question was: “To separate water and plastics, your teacher will select between a stream separator and a dissolver. Explain which is more appropriate.”. After we removed items that contributed the low reliability, the knowledge tests were reliable (greatest lower bound: pretest = 0.67; posttest = 0.70). Prior knowledge tests did not usually measure the same underlying construct (nine separators instead of one),

and a reliability value lower than 0.70 was acceptable (Taber, 2018). All multiple-choice questions had acceptable item discrimination (greater than 0.2) and item difficulty (ranging from 0.2 to 0.8; Cohen, Manion, & Morrison, 2018).

#### 2.3.4. Demographic information

Demographic information measured age and sex.

#### 2.3.5. Mental effort

The original Paas' (1992) scale was used to measure mental effort: "How much mental effort did this game level require from you" (1 = very, very low mental effort, 9 = very, very high mental effort).

#### 2.3.6. Achievement goals questionnaire

The achievement goals questionnaire (AGQ) was adopted from Bipp and Van Dam (2014), based on the Achievement Goals Questionnaire-Revised (Elliot & Murayama, 2008, 1 = strongly disagree, 5 = strongly agree) and measures state-based mastery-approach goals (e.g., "My goal is to learn as much as possible in the game") and performance-approach goals (e.g., "My goal is to perform better than other students"). To make the questionnaire state-based, the instruction of the questionnaire asked participants to describe how they feel at this moment (pretest: "The next 12 questions ask how you feel at this moment. At this moment ...") and how they felt during the game (posttest: "The next 12 questions ask how you felt during the game. During this game CosmicClean ..."). Because motivational constructs, such as achievement goals, vary across contexts (cf. e.g., Bong, 2001), the items were framed as goals for the game. The items of the mastery-approach goals focused on task-based goals instead of self-based goals. The AGQ was administered twice, once before the intervention started and once after it, with the same items but in a different order. The first AGQ was used to determine prior achievement goals and the second one to measure achievement goals after the achievement goal instructions. All subscales were reliable (greatest lower bound gave a reliability estimation ranging from 0.77 to 0.92). We expected that our reliability of state-based achievement goals is lower than trait-based achievement goals in the original AGQ-R (Cronbach's alpha ranging 0.84 to 0.92) because state-based achievement goals are more fluctuating than trait-based achievement goals (Pintrich, 2000).

#### 2.3.7. Achievement emotions questionnaire

The achievement emotions questionnaire (AEQ) was adapted from Donker et al. (2021), based on the Achievement Emotions Questionnaire (Pekrun et al., 2011). The 20 items assessed enjoyment (4 items; e.g., "I enjoyed it"), pride (3 items; e.g., "I was proud of myself"), anger (4 items; e.g., "I felt angry"), anxiety (3 items; e.g., "I was nervous"), boredom (3 items; e.g., "I was bored"), and shame (3 items; e.g., "I was ashamed"; 1 = strongly disagree, 5 = strongly agree). The instruction of the questionnaire asked participants to describe how they felt during the game ("The next 20 questions ask how you felt during the game. During this game CosmicClean ..."). All subscales were reliable (greatest lower bound ranging from 0.79 to 0.94), except for anxiety (greatest lower bound = 0.57) which was removed from further analysis.

### 2.4. Procedure

#### 2.4.1. Pilot study

We ran a pilot study with 57 participants to check whether they understood all the materials or whether they experienced technical problems with the online experiment in Gorilla (app.gorilla.sc) and Qualtrics (www.qualtrics.com). The unclear materials were changed. Participant indicated that they understood the achievement goal instructions.

#### 2.4.2. Experimental procedure

After giving informed consent (note that parental consent was

needed and obtained if participants are younger than 16 years old), participants received a written introduction about the number of sections, the duration, and the rules (e.g., answer carefully) of the experiment and completed the AGQ and prior knowledge test (pretest) in 15 min. Afterwards, they were randomly assigned to one of the four groups, read the achievement goal instructions, and finished gameplay within 1 h, during which they rated mental effort for each game level. Then they completed the demographic information, AEQ, AGQ, and post knowledge test (posttest) in 20 min.

### 2.5. Scoring, data preparation, and data analysis

For the knowledge test, we calculated a sum score of 12 multiple-choice questions (1 point per correct answer per question) and three open-ended questions (3 points per correct answer per question; partial credit is allowed), with a maximum score of 21 points. For the three open-ended questions, we developed a coding schema. Two raters first scored independently 10% of the pretest and posttest answers to each question to resolve disagreements (inter-rater reliability Cohen's  $k = 0.90$ ) and then scored the remainder ( $k = 0.89$ ). For AEQ and AGQ, we first calculated the scale means of all items. For the mental effort, we calculated its means of all single items across all game levels.

For RQ1 and RQ2, data were analyzed by robust regression using the lmrob function from the robustbase package (Maechler et al., 2021) in R studio (RStudio Team, 2022). All DVs violated the assumptions of normality of residuals and multivariate normality (Shapiro-Wilk test) and there were outliers ( $| \text{standardized residuals} | > 3$ ). The assumptions of homogeneity of variances (Levene's test), homogeneity of covariance matrices (Box's test), independence of residuals, linearity, and no multicollinearity (Field, Miles, & Field, 2012) were all met. We checked for missing data (less than 5%). As suggested by Field & Wilcox (2017), we chose robust regression because ANOVA or non-parametric ANOVA that are robust to skewness violations cannot handle outliers. We should run a robust multivariate regression with mastery-approach goal instructions (yes or no) and performance-approach goal instructions (yes or no) as the factors, mastery-approach goals, performance-approach goals, mental effort, posttest performance, enjoyment, pride, anger, boredom, and shame as the dependent variables, prior mastery-approach goals and performance-approach goals as moderators, and prior achievement goals and pretest performance as the covariates (see Figure A1 for Pearson correlation). However, since robust multivariate regression was currently unavailable in robustbase (M. Maechler, personal communication, January 20, 2023), we used robust regression for each dependent variable.

Participants (level 1) were nested within teachers (level 2). Our Intraclass Correlation Coefficients were low ( $< 0.08$ ). However, the sample size at level 2 ( $n = 7$ ) was too small for multilevel regression. As suggested by McNeish and Stapleton (2016), we dummy coded teachers and included them as predictors.

## 3. Results

Table 1 presents the means and standard deviations for the dependent variables and covariates. Table 2 presents robust regression results for main effects and moderation.

### 3.1. RQ1: the effect of achievement goal instructions on learning

There were no statistically significant interaction effects on all learning processes and outcomes. The main effects were explained below (see Table 2).

#### 3.1.1. Achievement goals

Robust regression revealed a statistically significant main effect of the performance-approach goal instructions on performance-approach goals ( $t = 1.97$ ,  $p = 0.049$ ,  $d = 0.18$ ) after controlling for teacher and

**Table 1**

Median and interquartile range for dependent variables and covariates.

	Mastery-approach goal instructions (n = 110)		Performance-approach goal instructions (n = 111)		Multiple goal instructions (n = 112)		No goal instructions (n = 117)	
	M	IQR	M	IQR	M	IQR	M	IQR
Prior mastery-approach goals (1–5)	3.67	0.67	4.00	0.67	4.00	0.67	3.67	0.67
Prior performance-approach goals (1–5)	3.33	0.92	3.33	1.00	3.67	1.33	3.33	1.00
Mastery-approach goals (1–5)	3.67	1.00	3.67	1.00	3.67	1.00	3.67	1.00
Performance-approach goals (1–5)	3.00	2.00	3.00	1.33	3.00	1.42	3.00	1.33
Pretest (0–14)	3.00	2.75	3.00	2.00	3.00	2.00	3.00	2.00
Posttest (0–21)	6.50	3.00	6.00	5.00	6.00	3.25	7.00	4.00
Mental effort (1–9)	3.61	1.67	3.39	1.64	3.78	2.22	3.50	2.39
Enjoyment (1–5)	3.25	1.25	3.50	1.50	3.00	1.31	3.5	1.25
Pride (1–5)	3.67	0.67	3.67	1.00	3.67	1.00	3.67	0.67
Anger (1–5)	2.25	1.25	2.25	1.38	2.25	1.50	2.25	1.75
Anxiety (1–5)	2.00	1.00	2.00	1.00	2.00	1.00	2.00	1.00
Boredom (1–5)	2.67	1.33	3.00	1.67	3.00	1.33	3.00	1.67
Shame (1–5)	1.67	0.67	1.67	0.67	1.67	1.08	1.67	1.33

Note. n = sample size per condition per outcome; M = median; IQR = interquartile range.

prior achievement goals. Participants receiving the performance-approach goal instructions reported higher performance-approach goals than those who did not receive the performance-approach goal instructions. There were no statistically significant main effects on mastery-approach goals after controlling for teacher and prior achievement goals. As a result, mastery-approach goal instructions were not included in the further analysis.

### 3.1.2. Mental effort and posttest performance

After controlling for teacher, pretest performance, and prior achievement goals, robust regression revealed a statistically significant main effect for performance-approach goal instructions on mental effort ( $t = 2.31, p = 0.021, d = 0.08$ ) and posttest performance ( $t = -1.99, p = 0.047, d = -0.19$ ). Participants receiving the performance-approach goal instructions reported higher mental effort but achieved lower posttest performance than those who did not receive the performance-approach goal instructions.

A paired  $t$ -test shows that there was a statistically significant difference between pretest performance and posttest performance ( $t = 8.19, df = 449, p < 0.001, d = 0.42$ ), so, learning happened.

### 3.1.3. Achievement emotions

Robust regression revealed no statistically significant main effects on achievement emotions.

## 3.2. RQ2: moderation effect of prior achievement goals

Robust regression revealed that there was a statistically significant interaction effect between prior mastery-approach goals and the performance-approach goal instructions ( $t = -2.26, p = 0.024$ ) on mental effort (see Table 2 and Figure A.2). With higher prior mastery-approach goals, participants who received the performance-approach goal instructions reported lower mental effort than those who did not receive the performance-approach goal instructions. There were no statistically significant moderating effects on achievement goals, posttest performance, and achievement emotions.

## 4. Discussion

Research on achievement goal instructions and their effects on secondary school students' achievement goals, mental effort, performance, and achievement emotions is sparse. To the best of our knowledge, this study is one of the first to present an integrated view on achievement goals, performance, and achievement emotions, and it appears to be the first to test how achievement goal instructions affect these three learning outcomes explained by the multiple goal perspective and moderated by prior achievement goals.

### 4.1. RQ1: the effect of achievement goal instructions on learning

We found that mastery-approach goal instructions and performance-approach goal instructions did not interact, mastery-approach goal instructions did not induce mastery-approach goals, while performance-approach goal instructions induced performance-approach goals, increased mental effort, and decreased posttest performance. These results indicated that the specialized mechanism, additive mechanism, and interactive mechanism of the multiple goal perspective were not supported.

#### 4.1.1. Achievement goals

Consistent with our hypothesis, there are positive main effects of performance-approach goal instructions on performance-approach goals. Contrary to our hypotheses but consistent with Muis et al. (2013), there are no main effects of mastery-approach goal instructions on mastery-approach goals. These results seem to indicate that performance-approach goal instructions work for secondary school students (i.e., young adolescents) in chemistry GBL, but mastery-approach goal instructions not. These results are consistent with previous studies on achievement goal interventions: Mastery goal interventions appear to be effective for primary school students (i.e., children) but not for undergraduates (i.e., late adolescents), whereas performance goal interventions appear to be effective for undergraduates but not for primary school students (e.g., Linnenbrink, 2005; Muis et al., 2013).

One explanation for these results is that there are age-related differences in the adoption of achievement goals. For example, children at primary school are more likely to adopt mastery-approach goals, whereas adolescents are more likely to adopt performance-approach goals (Bong, 2009). When evaluating competence, children at primary school are more likely to concentrate on the tasks and improving skills, whereas adolescents and young adults are more likely to concentrate on the performance of others (Dweck & Leggett, 1988). This age-related difference may be a result of the developmental stage of students (Bong, 2009) or of learning environments that emphasize social comparison in adolescents and young adults (Urdu & Midgley, 2003).

#### 4.1.2. Mental effort and posttest performance

Consistent with our hypothesis, there are positive main effects of performance-approach goal instructions on mental effort. Consistent with our hypothesis and previous studies (e.g., Erhel & Jamet, 2016; Muis et al., 2013), there are negative main effects of performance-approach goal instructions on posttest performance. These results imply that performance-approach goal instructions may hamper learning.

These results can be interpreted by considering the source of mental

**Table 2**

Robust regression results for main effects and moderation.

Variables	$\beta$	SE	t	p	R <sup>2</sup>	Adjusted R <sup>2</sup>
Outcome: Mastery-approach goals					0.44	0.43
(Intercept)	1.02	0.22	4.66	<0.001		
Teacher	−0.02	0.01	−1.82	0.069		
Prior mastery-approach goals	0.69	0.06	12.07	<0.001		
Prior performance-approach goals	0.03	0.04	0.81	0.416		
Mastery-approach goal instructions	0.06	0.05	1.20	0.230		
Performance-approach goal instructions	0.02	0.05	0.32	0.753		
Outcome: Performance-approach goals					0.62	0.61
(Intercept)	−0.18	0.19	−0.91	0.361		
Teacher	0.00	0.01	0.06	0.948		
Prior mastery-approach goals	0.19	0.06	3.23	0.001		
Prior performance-approach goals	0.80	0.04	18.48	<0.001		
Mastery-approach goal instructions	−0.06	0.06	−1.05	0.294		
Performance-approach goal instructions	0.12	0.06	1.97	0.049		
Outcome: Posttest performance					0.27	0.27
(Intercept)	4.31	0.86	4.97	<0.001		
Teacher	−0.15	0.07	−2.28	0.023		
Pretest performance	0.78	0.08	10.04	<0.001		
Prior mastery-approach goals	0.16	0.23	0.68	0.497		
Prior performance-approach goals	0.10	0.16	0.64	0.521		
Mastery-approach goal instructions	0.06	0.23	0.27	0.784		
Performance-approach goal instructions	−0.46	0.23	−1.99	0.047		
Outcome: Mental effort					0.06	0.04
(Intercept)	2.50	0.71	3.54	<0.001		
Teacher	−0.01	0.03	−0.21	0.837		
Pretest performance	−0.10	0.05	−2.15	0.032		
Prior mastery-approach goals	0.61	0.17	3.40	<0.001		
Prior performance-approach goals	−0.30	0.09	−3.35	<0.001		
Mastery-approach goal instructions	0.32	0.14	2.30	0.022		
Performance-approach goal instructions	2.30	1.00	2.31	0.021		
Prior mastery-approach goals*Performance-approach goal instructions	−0.60	0.27	−2.26	0.024		
Outcome: Enjoyment					0.21	0.20
(Intercept)	0.86	0.30	2.93	0.004		
Teacher	−0.02	0.02	−1.23	0.218		
Prior mastery-approach goals	0.57	0.07	8.23	<0.001		
Prior performance-approach goals	0.13	0.05	2.84	0.005		
Mastery-approach goal instructions	−0.01	0.08	−0.17	0.865		
Performance-approach goal instructions	−0.10	0.08	−1.28	0.209		
Outcome: Pride					0.11	0.10

**Table 2 (continued)**

Variables	$\beta$	SE	t	p	R <sup>2</sup>	Adjusted R <sup>2</sup>
(Intercept)	2.23	0.25	8.81	<0.001		
Teacher	0.01	0.01	0.86	0.539		
Prior mastery-approach goals	0.29	0.07	4.00	<0.001		
Prior performance-approach goals	0.09	0.05	1.81	0.071		
Mastery-approach goal instructions	0.05	0.06	0.74	0.457		
Performance-approach goal instructions	0.00	0.06	−0.01	0.994		
Outcome: Anger					0.05	0.04
(Intercept)	3.70	0.39	9.49	<0.001		
Teacher	0.02	0.02	0.79	0.429		
Prior mastery-approach goals	−0.38	0.10	−3.96	<0.001		
Prior performance-approach goals	0.01	0.07	0.17	0.868		
Mastery-approach goal instructions	−0.07	0.10	−0.66	0.511		
Performance-approach goal instructions	0.02	0.10	0.22	0.828		
Outcome: Boredom					0.11	0.10
(Intercept)	4.79	0.32	14.88	<0.001		
Teacher	0.01	0.02	0.40	0.688		
Prior mastery-approach goals	−0.54	0.08	−6.66	<0.001		
Prior performance-approach goals	0.01	0.06	0.14	0.888		
Mastery-approach goal instructions	−0.03	0.09	−0.31	0.757		
Performance-approach goal instructions	0.04	0.09	0.48	0.635		
Outcome: Shame					0.02	0.01
(Intercept)	2.00	0.23	8.22	<0.001		
Teacher	−0.04	0.02	−2.53	0.012		
Prior mastery-approach goals	−0.06	0.06	−0.98	0.329		
Prior performance-approach goals	0.03	0.04	0.53	0.594		
Mastery-approach goal instructions	0.00	0.06	0.01	0.990		
Performance-approach goal instructions	0.02	0.06	0.30	0.766		

Note.  $N = 450$ ;  $\beta$  = regression coefficient; SE = standard error;  $t$  = test whether  $\beta$  is significantly differ from zero;  $R^2$  = the proportion of the variance of the outcome that is explained by the model; Only statistically significant moderators (prior mastery-approach goals or prior performance-approach goals) are kept in the models; Because the interaction effects between mastery-approach goal instructions and performance-approach goal instructions are not statistically significant, all models do not include the interaction effects; Dummy coding: yes = 1, no = 0.

effort. Participants in the performance-approach goal instructions group were required to finish as fast as possible, so, their attention may have been diverted from the game activities that are directly related to learning to interfering thoughts (Sarason et al., 1986), such as winning, or to coping with the imposed time pressure. These are both processes irrelevant for learning. According to CLT (Sweller et al., 2019), they might have experienced higher extraneous load, that is, they exerted higher mental effort, but got lower posttest performance.

#### 4.1.3. Achievement emotions

Contrary to our hypothesis, there are no main effects of performance-approach goal instructions on outcome emotions. One possibility is that the achievement goal instructions may indeed affect specific achievement emotions, but the measurement method we used may not be sensitive enough to detect this effect. Research on the temporal dynamics of



emotional experiences during complex learning suggested that based on duration, emotions can be classified as persistent states that last for a while (e.g., boredom, engagement/flow, and confusion), transitory states that dissipate almost immediately (e.g., delight and surprise), and intermediate states (e.g., frustration; D'Mello & Graesser, 2011). If this categorization also applies to achievement emotions, then the timing of measuring emotions may need to change accordingly. For example, transitory achievement emotions should be measured in real time rather than delayed (e.g., after gameplay in this study). Future studies could use real-time measures (Pekrun & Linnenbrink-Garcia, 2014), such as experience sampling method, to capture emotional trajectories during tasks.

#### 4.2. RQ2: moderation effect of prior achievement goals

Contrary to our hypothesis, prior performance-approach goals did not moderate the effects of performance-approach goal instructions. Consistent with our hypothesis, prior mastery-approach goals moderated the effects of performance-approach goal instructions on mental effort. For the performance-approach goal instructions group, the higher the prior mastery-approach goals, the lower the mental effort. This result implies that performance-approach goal instructions have weaker positive influences on learning when learners hold higher prior mastery-approach goals than lower prior mastery-approach goals. This is also in line with the vibration effect from the mismatch hypothesis (i.e., a beneficial effect is weakened, if achievement goal instructions mismatch prior achievement goals; Murayama & Elliot, 2009). Overall, our results do not support the match hypothesis and partially support the mismatch hypothesis (a vibration effect).

Combining with previous research, the evidence for the match and mismatch hypotheses seems inconclusive. Similar to our results, most of the supportive evidence is limited to certain learning processes and outcomes, such as effort (Wolters, 2004), metacognitive self-regulation (Muis et al., 2013), or intrinsic motivation (Murayama & Elliot, 2009) but not others, such as test result (Linnenbrink, 2005), course grade (Muis et al., 2013; Wolters, 2004), or test anxiety (Wolters, 2004). This implies that prior achievement goals may moderate the effects of achievement goal interventions on some but not all learning processes and outcomes, which needs more research in the future.

#### 4.3. Limitations

Some limitations need attention to evaluate our results. First, we focused only on achievement goals. Considering that learners enter a learning environment with many goals, such as getting a high grade in chemistry, future research should assess whether goal instructions have a similar effect on goals other than achievement goals.

Second, we employed a distinct game-based learning environment featuring a unique game genre known as CosmiClean, which integrates elements of computer, puzzle, and strategy games. Notably, CosmiClean diverges from conventional games by omitting in-game scoring systems or achievement badges. Instead, whether participants do better than others (performance-approach goals) are indicated by whether they finish faster than others upon concluding gameplay. It's worth noting that exploring performance-approach goal instructions via alternative in-game indicators may yield divergent outcomes. For instance, the introduction of a leaderboard following each level might provide participants with more frequent feedback on their comparative performance, potentially amplifying the effects of performance-approach goal instructions beyond those observed in our study. Hence, we advocate for further investigations employing diverse games and alternative performance-related indicators to validate our findings and enrich the existing body of research in this domain.

Third, this study may be influenced by *pretest effects*, that is, a pretest might cause learning before the learning materials are presented (i.e., a testing effect; Mayer, 2021) and may direct participants' attention to the

relevant topics that researchers are interested in and alert them to the posttest and interventions (i.e., a priming effect; Kim & Willson, 2010). According to the meta-analysis on pretest effects in experimental studies, the effect size of a pretest on a posttest is small if there is less one day between pretest and posttest (Willson & Putnam, 1982). To minimize the impact of a potential pretest effect, we added pretest performance as a covariate. To prevent pretest effects, future research may use Solomon four-group design: a) two groups (control 1 and treatment 1) receive pretest and posttest and another two groups (control 2 and treatment 2) receive only posttest and b) the effects of the pretest and intervention can be evaluated by comparing control groups and comparing treatment groups, respectively (Navarro & Siegel, 2018).

Fourth, this study used self-reported mental effort to measure cognitive load. Although some researchers have challenged the idea that self-reported mental effort scale by Paas (1992) provides a reliable indicator of cognitive load (e.g., Hoch et al., 2023), it is as valid and reliable as objective techniques and it is easier to use (e.g., Szulewski et al., 2018). Thus, as suggested by Sweller et al. (2019), we used this scale as an overall measure of cognitive load in this study.

Fifth, this study tested the multiple goal perspective which focused on the main effects and interaction effects of mastery-approach goal instructions and performance-approach goal instructions. Notably, according to the *mastery goal perspective* (Barron & Harackiewicz, 2001), mastery goals are typically adaptive given that mastery-oriented individuals tend to seek out challenge and persist in the face of difficulty, whereas performance goals are typically maladaptive given that performance-oriented individuals tend to avoid challenge (Dweck & Leggett, 1988). Hence, it would be worthwhile to compare mastery-approach goal instructions condition and performance-approach goal instructions condition. We advocate further investigations to this end.

#### 4.4. Implications

Practically, educators aim to implement instructions that foster learners' cognitive, motivational, and positive emotional processes and outcomes. First, considering that achievement goals are frequently used in learning environments, we suggest that educators can use achievement goal instructions to induce some achievement goals (e.g., performance-approach goals) but not others (e.g., mastery-approach goals) in chemistry GBL. Second, our findings suggest that educators may change achievement goal instructions for different learning goals. If the learning goal is to promote posttest performance in chemistry GBL, we suggest that educators should not use performance-approach goal instructions. Third, when using achievement goal instructions, educators would do well to take students' prior achievement goals into account.

Theoretically, instructional design features that manipulate motivation, such as performance-approach goal instructions, can affect not only motivation, such as performance-approach goals, but also cognition, such as mental effort and posttest performance. Currently, we do not fully understand how motivation, cognition, and emotion interact in learning environments (Dietrich et al., 2022; Mayer, 2021; Pekrun & Linnenbrink-Garcia, 2014; Sweller et al., 2019). Future research on the interactions between motivation, emotion and cognition will help us understand and change learning processes and outcomes.

### 5. Conclusion

We conclude that performance-approach goal instructions affect cognitive and motivational processes and outcomes differently in GBL. Consequently, educators may design the achievement goal instructions based on learner's prior achievement goals and the learning goals, such as promoting posttest performance. This study is one of the few to attend to achievement goal instructions in GBL. In addition, this study is one of the first to manipulate multiple goals and to focus on motivational,

cognitive, and emotional processes and outcomes. This study is the first experimental study that supports the vibration effect of the mismatch hypotheses. The results of this study may advance the field of achievement goal theory and instructional design by our findings that achievement goal instructions partially affect learners' achievement goals, mental effort, and performance, and that prior mastery-approach goals moderate the effects of performance-approach goal instructions on learning processes and outcomes (mental effort).

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## CRediT authorship contribution statement

**Yuan Yuan Hu:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Pieter Wouters:** Supervision, Writing – review & editing. **Marieke van der Schaaf:** Supervision, Writing – review & editing. **Liesbeth Kester:** Supervision, Writing – review & editing.

## Declaration of competing interest

None.

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## Appendix A. Supplementary data

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## References

- Hu, Y., Gallagher, T., Wouters, P., van der Schaaf, M., & Kester, L. (2021). Game-based learning has good chemistry with chemistry education: A three-level meta-analysis. *Journal of Research in Science Teaching*, 1–45. <https://doi.org/10.1002/tea.21765>.
- Hu, Y., Wouters, P., van der Schaaf, M., & Kester, L. (2024). *Timing of information presentation matters: Effects on cognition, motivation, and emotions for secondary school students in game-based learning* [Manuscript submitted for publication].
- Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives: complete edition*. Addison Wesley Longman.
- Barron, K. E., & Harackiewicz, J. M. (2001). Achievement goals and optimal motivation: Testing multiple goal models. *Journal of Personality and Social Psychology*, 80, 706–722. <https://doi.org/10.1037/0022-3514.80.5.706>
- Bipp, T., & Van Dam, K. (2014). Extending hierarchical achievement motivation models: The role of motivational needs for achievement goals and academic performance. *Personality and Individual Differences*, 64, 157–162. <https://doi.org/10.1016/j.paid.2014.02.039>
- Bong M. (2001). Between- and within-domain relations of academic motivation among middle and high school students: Self-efficacy, task-value, and achievement goals. *Journal of Educational Psychology*, 93, 23–34. <https://doi.org/10.1037/0022-0663.93.1.23>
- Bong M. (2009). Age-related differences in achievement goal differentiation. *Journal of Educational Psychology*, 101(4), 879–896. <https://doi.org/10.1037/a0015945>
- D'Mello, S., & Graesser, A. (2011). The half-life of cognitive-affective states during complex learning. *Cognition & Emotion*, 25(7), 1299–1308. <https://doi.org/10.1080/02699931.2011.613668>
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th edition). Routledge.
- Dietrich, J., Schmiedek, F., & Moeller, J. (2022). Academic motivation and emotions are experienced in learning situations, so let's study them. *Introduction to the special issue. Learning and Instruction*, 101623. <https://doi.org/10.1016/j.learninstruc.2022.101623>
- Donker, M. H., van Vemde, L., Hessen, D. J., van Gog, T., & Mainhard, T. (2021). Observational, student, and teacher perspectives on interpersonal teacher behavior: Shared and unique associations with teacher and student emotions. *Learning and Instruction*, 73, 101414. <https://doi.org/10.1016/j.learninstruc.2020.101414>
- Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review*, 95, 256–273. <https://doi.org/10.1037/0033-295X.95.2.256>
- Eccles, J. S., Wigfield, A., Midgley, C., Reuman, D., Iver, D. M., & Feldlaufer, H. (1993). Negative effects of traditional middle schools on students' motivation. *The Elementary School Journal*, 93(5), 553–574. <https://doi.org/10.1086/461740>
- Elliot, A. J., & Hulleman, C. S. (2017). Achievement goals. In A. J. Elliot, C. S. Dweck, & D. S. Yeager (Eds.), *Handbook of competence and motivation: Theory and application* (pp. 43–60). The Guilford Press.
- Elliot, A. J., & Murayama, K. (2008). On the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology*, 100(3), 613–628. <https://doi.org/10.1037/0022-0663.100.3.613>
- Erhel, S., & Jamet, E. (2013). Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness. *Computers & Education*, 67, 156–167. <https://doi.org/10.1016/j.compedu.2013.02.019>
- Erhel, S., & Jamet, E. (2016). The effects of goal-oriented instructions in digital game-based learning. *Interactive Learning Environments*, 24(8), 1744–1757. <https://doi.org/10.1080/10494820.2015.1041409>
- Erhel, S., & Jamet, E. (2019). Improving instructions in educational computer games: Exploring the relations between goal specificity, flow experience and learning outcomes. *Computers in Human Behavior*, 91, 106–114. <https://doi.org/10.1016/j.chb.2018.09.020>
- Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G\*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. SAGE Publications.
- Field, A. P., & Wilcox, R. R. (2017). Robust statistical methods: A primer for clinical psychology and experimental psychopathology researchers. *Behaviour Research and Therapy*, 98, 19–38. <https://doi.org/10.1016/j.brat.2017.05.013>
- Hawitschek, A., & Joeckel, S. (2017). Increasing the effectiveness of digital educational games: The effects of a learning instruction on students' learning, motivation and cognitive load. *Computers in Human Behavior*, 72, 79–86.
- Hoch, E., Sidi, Y., Ackerman, R., Hoogerheide, V., & Scheiter, K. (2023). Comparing mental effort, difficulty, and confidence appraisals in problem-solving: A metacognitive perspective. *Educational Psychology Review*, 35(2), 61. <https://doi.org/10.1007/s10648-023-09779-5>
- Hofverberg, A., & Winberg, M. (2020). Achievement goals and classroom goal structures: Do they need to match? *The Journal of Educational Research*, 113(2), 145–162. <https://doi.org/10.1080/00220671.2020.1759495>
- Hu, Y., Elliot, A. J., Wouters, P., van der Schaaf, M., Kester, L., & Pekrun, R. (2024). Effects of peers' emotions on students' emotions, achievement goals, mental effort, and performance. *Journal of Educational Psychology* (in press).
- Huang, C. (2011). Achievement goals and achievement emotions: A meta-analysis. *Educational Psychology Review*, 23(3), 359. <https://doi.org/10.1007/s10648-011-9155-x>
- Kim, E. S., & Willson, V. L. (2010). Evaluating pretest effects in pre-post studies. *Educational and Psychological Measurement*, 70(5), 744–759. <https://doi.org/10.1177/0013164410366687>
- Kriegelstein, F., Beege, M., Rey, G. D., Ginns, P., Krell, M., & Schneider, S. (2022). A systematic meta-analysis of the reliability and validity of subjective cognitive load questionnaires in experimental multimedia learning research. *Educational Psychology Review*, 1–57. <https://doi.org/10.1007/s10648-022-09683-4>
- Lau, S., & Nie, Y. (2008). Interplay between personal goals and classroom goal structures in predicting student outcomes: A multilevel analysis of person-context interactions. *Journal of Educational Psychology*, 100(1), 15–29. <https://doi.org/10.1037/0022-0663.100.1.15>
- Linnenbrink, E. A. (2005). The dilemma of performance-approach goals: The use of multiple goal contexts to promote students' motivation and learning. *Journal of Educational Psychology*, 97(2), 197–213. <https://doi.org/10.1037/0022-0663.97.2.197>
- Loderer, K., Pekrun, R., & Plass, J. L. (2020). Emotional foundations of game-based learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 111–151). MIT Press.
- Maechler, M., Rousseeuw, P., Croux, C., Todorov, V., Ruckstuhl, A., Salibián-Barrera, M., ... di Palma, M. A. (2021). Package 'robustbase'. *Basic Robust Statistics*, 2021.
- Mayer, R. E. (2021). *The Cambridge handbook of multimedia learning*. Cambridge University Press.
- McNeish, D. M., & Stapleton, L. M. (2016). The effect of small sample size on two-level model estimates: A review and illustration. *Educational Psychology Review*, 28(2), 295–314. <https://doi.org/10.1007/s10648-014-9287-x>
- Miller, C. S., Lehman, J. F., & Koedinger, K. R. (1999). Goals and learning in microworlds. *Cognitive Science*, 23(3), 305–336. [https://doi.org/10.1016/S0364-0213\(99\)00007-5](https://doi.org/10.1016/S0364-0213(99)00007-5)
- Muis, K. R., Ranellucci, J., Franco, G. M., & Crippen, K. J. (2013). The interactive effects of personal achievement goals and performance feedback in an undergraduate science class. *The Journal of Experimental Education*, 81(4), 556–578. <https://doi.org/10.1080/00220973.2012.738257>

- Murayama, K., & Elliot, A. J. (2009). The joint influence of personal achievement goals and classroom goal structures on achievement-relevant outcomes. *Journal of Educational Psychology*, 101(2), 432–447. <https://doi.org/10.1037/a0014221>
- Navarro, M., & Siegel, J. T. (2018). Solomon four-group design. In B. B. Frey (Ed.), *The SAGE encyclopedia of educational research, measurement, and evaluation*. SAGE Publications.
- Nebel, S., Schneider, S., Schledjewski, J., & Rey, G. D. (2017). Goal-setting in educational video games: Comparing goal-setting theory and the goal-free effect. *Simulation & Gaming*, 48(1), 98–130. <https://doi.org/10.1177/1046878116680869>
- Niemivirta, M. (2002). Motivation and performance in context: The influence of goal orientations and instructional setting on situational appraisals and task performance. *Psychologia: An International Journal of Psychology in the Orient*, 45(4), 250–270. <https://doi.org/10.2117/psysoc.2002.250>
- Noordzij, G., Giel, L., & van Mierlo, H. (2021). A meta-analysis of induced achievement goals: The moderating effects of goal standard and goal framing. *Social Psychology of Education*, 24(1), 195–245. <https://doi.org/10.1007/s11218-021-09606-1>
- Paas, F. G. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, 84(4), 429. <https://doi.org/10.1037/0022-0663.84.4.429>
- Pahljina-Reinić, R., & Kolić-Vehovec, S. (2017). Average personal goal pursuit profile and contextual achievement goals: Effects on students' motivation, achievement emotions, and achievement. *Learning and Individual Differences*, 56, 167–174. <https://doi.org/10.1016/j.lindif.2017.01.020>
- Pekrun, R., Cusack, A., Murayama, K., Elliot, A. J., & Thomas, K. (2014). The power of anticipated feedback: Effects on students' achievement goals and achievement emotions. *Learning and Instruction*, 29, 115–124. <https://doi.org/10.1016/j.learninstruc.2013.09.002>
- Pekrun, R., Elliot, A. J., & Maier, M. A. (2006). Achievement goals and discrete achievement emotions: A theoretical model and prospective test. *Journal of Educational Psychology*, 98(3), 583–597. <https://doi.org/10.1037/0022-0663.98.3.583>
- Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of Educational Psychology*, 101(1), 115–135. <https://doi.org/10.1037/a0013383>
- Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, 36(1), 36–48. <https://doi.org/10.1016/j.cedpsych.2010.10.002>
- Pekrun, R., & Linnenbrink-Garcia, L. (2014). *International handbook of emotions in education*. Routledge.
- Pintrich, P. R. (2000). An achievement goal theory perspective on issues in motivation terminology, theory, and research. *Contemporary Educational Psychology*, 25, 92–104. <https://doi.org/10.1006/ceps.1999.1017>
- Plass, J. L., Mayer, R. E., & Homer, B. D. (2020). *Handbook of game-based learning*. MIT Press.
- RStudio Team. (2022). *RStudio*. Boston, MA: Integrated Development for R. RStudio, PBC. URL <http://www.rstudio.com/>.
- Sarason, I. G., Sarason, B. R., Keefe, D. E., Hayes, B. E., & Shearin, E. N. (1986). Cognitive interference: Situational determinants and traitlike characteristics. *Journal of Personality and Social Psychology*, 51(1), 215. <https://doi.org/10.1037/0022-3514.51.1.215>
- Strunk, K. K., Lester, W. S., Lane, F. C., Hoover, P. D., & Betties, J. S. (2020). Testing the mastery-avoidance construct in achievement goal theory: A meta-analytic confirmatory factor analysis (MA-CFA) of two achievement goals scales. *Educational Psychology*, 1–18. <https://doi.org/10.1080/01443410.2020.1824268>
- Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31(2), 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Szulewski, A., Gegenfurtner, A., Howes, D. W., Sivilotti, M. L. A., & van Merriënboer, J. J. G. (2018). Measuring physician cognitive load: Validity evidence for a physiologic and a psychometric tool. *Advances in Health Sciences Education*, 22, 951–968. <https://doi.org/10.1007/s10459-016-9725-2>
- Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, 48, 1273–1296. <https://doi.org/10.1007/s11165-016-9602-2>
- Urdu, T., & Midgley, C. (2003). Changes in the perceived classroom goal structure and pattern of adaptive learning during early adolescence. *Contemporary Educational Psychology*, 28(4), 524–551. [https://doi.org/10.1016/S0361-476X\(02\)00060-7](https://doi.org/10.1016/S0361-476X(02)00060-7)
- Utman, C. H. (1997). Performance effects of motivational state: A meta-analysis. *Personality and Social Psychology Review*, 1(2), 170–182. [https://doi.org/10.1207/s15327957pspr0102\\_4](https://doi.org/10.1207/s15327957pspr0102_4)
- van Yperen, N., Blaga, M., & Postmes, T. (2015). A meta-analysis of the impact of situationally induced achievement goals on task performance. *Human Performance*, 28(2), 165–182. <https://doi.org/10.1080/08959285.2015.1006772>
- Vandercruysse, S., Desmet, E., Vandewaetere, M., & Elen, J. (2015). Integration in the curriculum as a factor in math-game effectiveness. In J. Torbeyns, et al. (Eds.), *Describing and studying domain-specific serious games* (pp. 133–153). Springer.
- Willson, V. L., & Putnam, R. R. (1982). A meta-analysis of pretest sensitization effects in experimental design. *American Educational Research Journal*, 19(2), 249–258.
- Wolters, C. A. (2004). Advancing achievement goal theory: Using goal structures and goal orientations to predict students' motivation, cognition, and achievement. *Journal of Educational Psychology*, 96(2), 236–250. <https://doi.org/10.1037/0022-0663.96.2.236>