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ORIGINAL RESEARCH

The role of motivational profiles in learning problem-solving and self-assessment skills with video modeling examples

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Abstract

In the current study, we examine the role of situation-specific motivational profiles in the effectiveness of video modeling examples for learning problem-solving and self-assessment accuracy in the domain of biology. A sample of 342 secondary school students participated in our study. Latent profile analysis resulted in four motivational profiles: (a) good-quality profile (high autonomous motivation, moderate introjected and external motivation), (b) moderately positive profile (moderate motivation levels with relatively higher autonomous motivation), (c) moderately negative profile (moderate motivation levels with relatively higher external motivation), and (d) poor-quality profile (moderate external, low autonomous motivation). Findings showed students with good-quality or moderately positive profiles learned more from the video modeling in terms of problem-solving and self-assessment accuracy than students with poor-quality or moderately negative profiles. Furthermore, students with a moderately negative profile outperformed students with a poor-quality profile on problem-solving and self-assessment accuracy. Results further indicated that students with good-quality and moderately positive profiles experienced studying the video modeling examples as less effortful than students with poor-quality or moderately negative profiles. Overall, our results demonstrated that knowing about students' motivational profiles could help explain differences in how well students learn problem-solving as well as self-assessment skills from watching video modeling examples.

Keywords Motivational profiles · Self-determination theory · Self-assessment accuracy · Mental effort · Video modeling examples

It is generally agreed that motivation is essential for optimal learning in school (e.g., Deci et al. 1991; Pintrich 2003; Ryan and Deci 2016). Motivation refers to students' reasons that drive their behavior, such as engaging in schoolwork. However, students' behavior is usually driven by multiple reasons simultaneously, such as interest in the learning materials,

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a desire to get good grades, and future personal growth (Vansteenkiste et al. 2009). These different motives are not equally important to all students, and some motives might be more dominant in determining individual students' behavior than others. Prior research has indicated that students can fall into distinct subgroups that differ in the configuration of motives that drive their behavior. Person-centered approaches to data analysis have become increasingly popular (e.g., Gillet et al. 2017; Ratelle et al. 2007; Vansteenkiste et al. 2009) for identifying these subgroups with different motivational profiles. The current study aims to investigate whether differences in students' situation-specific motivational profiles affect the effectiveness of video-modeling examples for learning problem-solving and self-assessment skills in the context of a biology task.

Motivation and motivational profiles

In this study, motivation is viewed from the perspective of self-determination theory (SDT). According to SDT, the quality of a learner's motivation, determined by the reasons driving their behavior, is more important than the overall amount of motivation for predicting desired learning outcomes and depth of processing (Deci and Ryan 2000, 2008; Ryan and Deci 2000, 2020; Vansteenkiste et al. 2006). Deci and Ryan (2000) proposed a self-determination continuum ranging from intrinsic motivation to amotivation, with several types of extrinsic motivation (i.e., integrated, identified, introjected, external) between, which differ in the amount of autonomy that is experienced. An important distinction is made between autonomous and controlled motivation.

Autonomously motivated students experience volition and psychological freedom (Deci and Ryan 2000, 2008; Ryan and Deci 2000, 2020). Autonomous motivation consists of three subtypes: intrinsic, integrated, and identified motivation. Students with intrinsic motivation study out of individual interest. Students with identified motivation believe that engaging in the activity is valuable for attaining personal goals or growth. Integrated motivation is the most autonomous form of extrinsic motivation. Students with integrated motivation recognize and identify with the value of the activity and experience doing the activity to be congruent with their core values and interests (e.g., doing schoolwork because it is part of who you are). Integrated motivation is often not measured in education (Sheldon et al. 2017) due to difficulties measuring it in self-reports (Gagné et al., 2015). Furthermore, secondary school students are still developing their identities (Verhoeven et al. 2019), making it difficult to respond to items measuring integrated motivation (see Guay et al. 2020).

Controlled motivation concerns the experience of coercion or pressure (Deci and Ryan 2000, 2008; Ryan and Deci 2000, 2020). Students experience introjected motivation when feelings of pressure come from within (e.g., shame or guilt, a desire to get good grades); however, when these feelings are external to the individual (e.g., demands or coercion by others) external motivation is experienced. Finally, amotivation is characterized by a lack of motivation to engage in an activity. Prior research has demonstrated that autonomous types of motivation are positively associated with optimal learning outcomes, such as academic achievement (Taylor et al. 2014) and better effort regulation, planning, and monitoring (Baars et al. 2017; León et al. 2015; Mukhtar et al. 2018). Introjected, external, and amotivation were negatively associated with academic achievement (Taylor et al. 2014).

However, research has shown that autonomous and controlled motivations for engaging in schoolwork can co-occur in the same student (Vansteenkiste et al. 2009). Therefore, it is important to know whether endorsing both motives can be beneficial for learning or whether it is better only to endorse autonomous reasons for studying. To gain an overview of current research on motivational profiles in education, we conducted a review of 28 studies reported in 22 papers (see Appendix A). Prior research on motivational profiles in education using a person-centered approach identified between two to six motivational profiles (mode = 4 profiles; Baars and Wijnia 2018; Boiché and Stephan 2014; Cannard et al. 2016; Cents-Boonstra et al. 2019; Corpus and Wormington 2014; Ganotice et al. 2020; Gillet et al. 2017; González et al. 2012; Hayenga and Corpus 2010; Hill 2013; Kong and Liu 2020; Kusurkar et al. 2013; Litalien et al. 2019; Oga-Baldwin and Fryer 2018, 2020; Pugh 2019; Ratelle et al. 2007; Vanslambrouck et al. 2018; Vansteenkiste et al. 2009; Wang et al. 2017; Wormington et al. 2012; Zhang and Lin 2020). In these studies, naturally occurring motivational profiles for engaging in school tasks or studying were examined in primary, secondary, or higher education. We excluded studies conducted in physical education (e.g., Boiché et al. 2008), sports (e.g., Gillet et al. 2013), or work (e.g., Van den Broeck et al. 2013) from this overview.

Although different labels have been used, the most commonly identified motivational profiles in education are (a) good-quality, (b) poor-quality, (c) high-quantity, and (d) low-quantity profiles (e.g., González et al. 2012; Hayenga and Corpus 2010; Kusurkar et al. 2013; Vansteenkiste et al. 2009; Wormington et al. 2012). Students with a good-quality profile have high levels of autonomous motivation and low levels of controlled motivation, whereas students with a poor-quality profile experience higher levels of controlled motivation and low autonomous motivation. Both profiles were identified in 21 studies (see Appendix A). A high-quantity profile (identified in 25 studies) is characterized by students who have high scores on autonomous as well as controlled motivation subscales. In contrast, a low-quantity profile (identified in 18 studies) is characterized by low scores on autonomous and controlled motivation.

All four motivational profiles were detected in only 11 of the studies. Furthermore, additional or other profiles have been identified in education. For example, in 15 studies, moderate motivational profiles were identified, in which students have moderate levels of autonomous and controlled motivation (e.g., Boiché and Stephan 2014; Hill 2013; Ratelle et al. 2007). In the study by Gillet et al. (2017), a further distinction was made between a "moderately autonomous" and a "moderately unmotivated" profile. The "moderately autonomous" profile was characterized by moderately high levels of autonomous motivation and low levels of controlled motivation, whereas the "moderately unmotivated" profile was made up of students with moderately low levels of autonomous motivation and average levels of controlled motivation. Baars and Wijnia (2018) also found two types of moderate profiles, a "moderately positive" and a "moderately negative" motivational profile. The moderately positive profile was characterized by higher scores on autonomous motivation and lower external motivation than the moderately negative profile.

Motivational profiles have different associations with student learning outcomes. Vansteenkiste et al. (2009) demonstrated that the good-quality motivational profile was associated with the most optimal learning outcomes (e.g., academic performance, deep learning, self-study time) when compared to the other motivational profiles, followed closely by the high-quantity profile. Some studies have suggested that the good-quality and high-quantity profiles are equally beneficial for academic achievement (Gillet et al. 2017; Ratelle et al. 2007). The latter finding suggests that controlled motivation is not always maladaptive for learning when it co-occurs with high levels of autonomous motivation (see Gillet et al. 2017; Wormington et al. 2012). Furthermore, Gillet et al. (2017) found that the good-quality, high-quantity, and moderately autonomous profiles scored similarly on academic achievement, which suggests that it is important that students experience moderate to high levels of autonomous motivation.

There are several differences among the studies investigating motivational profiles in education. Some of these differences might explain discrepancies that have been found concerning the number and type of profiles. Ratelle et al. (2007) argued that motivational profiles could be context sensitive. For example, they found a good-quality profile in their college sample, but not in their high school samples (see Appendix A). They argued that college students experience more autonomy in their learning environment. In contrast, in high school, there are more external controls and constraints, as students must still adhere to many rules, making it more challenging to develop an autonomous/good-quality profile.

Other differences between the studies are the type of person-centered method that was used (i.e., cluster analysis or latent profile analysis) and how academic motivation was operationalized (see Gillet et al. 2017). For example, some studies only incorporated the higher order dimensions of autonomous and controlled motivation (e.g., Vansteenkiste et al. 2009), whereas others used a finer-grained representation of motivation by including the motivation subscales for intrinsic, identified, introjected, and external motivation (e.g., Baars and Wijnia 2018; Gillet et al. 2017; Ratelle et al. 2007). As can be seen in Appendix A, moderate profiles were more commonly identified when a finer-grained representation of motivation was used.

Studies also differed in whether or not amotivation was measured. When amotivation was measured, it usually had a similar pattern as controlled motivation in the poor- and good-quality profiles. However, high-quantity profiles were more likely to be associated with low or below-average levels of amotivation and high levels of controlled and autonomous motivation (Boiché and Stephan 2014; Gillet et al. 2017; Litalien et al. 2019; Ratelle et al. 2007), whereas in low-quantity profiles, low autonomous and controlled motivation could co-occur with either low or high amotivation (Cannard et al. 2016; see Appendix A).

Finally, the level at which motivation was operationalized differed across the studies. Motivation can operate on different levels (Vallerand 1997), such as the trait, contextual (e.g., school), and situational level (e.g., motivation for a specific task or at a particular moment). Most of the studies in education examined contextual motivational profiles for studying in general, with a few exceptions, such as motivation for a specific school subject (see Oga-Baldwin and Fryer 2018, 2020) or for a particular task (see Baars and Wijnia 2018). In the current study, we examine students' motivation for learning to do a specific task. This is an example of situation-specific motivation that operates on the state level and is influenced by the task characteristics and other situational factors that occur at that moment, in addition to students' general motivation for school (Vallerand 1997). In particular, we investigate students' motivation for studying video-modeling examples about learning to solve and self-assess performance on heredity problems in biology.

Video modeling examples for learning problem-solving and self-assessment skills

A large body of experimental research has shown that (video) modeling examples are an effective form of instruction for novice learners who are in the early stages of skill acquisition for a task (see Van Gog and Rummel 2010; Van Gog et al. 2019). In video modeling examples, students watch a video demonstration of a task being performed by another person, such as a teacher, expert, or peer. Video modeling examples have been found effective for learning highly structured skills, such as learning to solve well-structured problems in math (e.g., Hoogerheide et al. 2016a), electrical troubleshooting (e.g., Hoogerheide et al. 2016b), and genetics problem-solving (e.g., Kostons et al. 2012). Well-structured problems have a clearly defined goal state and solution path (Jonassen 1997).

However, (video) modeling examples have also been found to be effective for learning less structured skills, such as collaboration (Rummel and Spada 2005) and self-assessing your performance (Kostons et al. 2012). Self-assessment involves retrospective monitoring of performance against some standard, goal, or criterion (Baars et al. 2014; Panadero et al. 2016). It is assumed that self-assessment will help learners to regulate their learning better by enabling them to make decisions about which tasks to complete next or where to focus their resources, which will, in turn, lead to better learning outcomes (Bjork et al. 2013; Nelson and Narens 1990; Zimmerman 2000). However, making monitoring judgments of one's performance is a difficult skill. Prior research has indicated that adult learners, as well as children, often make inaccurate judgments and overestimate their performance (e.g., Koriat and Shitzer-Reichert 2002; Lipko et al. 2009; Rawson and Dunlosky 2007). Furthermore, research has shown that students do not acquire self-assessment skills automatically, but need additional support to learn these skills, for example, through modeling (Kostons et al. 2012; Raaijmakers et al. 2018).

Kostons et al. (2012) used video modeling examples to help secondary education students learn how to solve genetics problems and to accurately self-assess their performance on these problems. In these videos, students first watched the model demonstrate how to solve a genetics problem. A subsequent video showed the model accurately self-assessing his/her performance by assigning one point for each correctly completed step in the problem-solving task. The results of the study demonstrated that video modeling examples were effective for learning how to solve genetics problems and how to self-assess one's performance. Nevertheless, substantial differences in learning gains (i.e., pretest to posttest problem-solving performance) were found, indicating that some students might have benefitted less from the video modeling examples than others. Another study found similar large differences in learning gains (Raaijmakers et al. 2018).

Kostons et al. (2012) mentioned differences in motivation as a possible explanation for the differences in learning gains. To this end, we investigate if students can be classified into different subgroups according to their motivation for studying the video modeling examples and whether this can explain why some students learn more from the video modeling examples than others. Baars and Wijnia (2018) investigated whether students with various motivational profiles had different learning outcomes and self-assessment accuracy after watching video modeling examples. They showed that students with a poor-quality motivation profile scored lower on the biology problems and self-assessment accuracy after watching video modeling examples than students with good-quality or moderate motivational profiles. However, they did not assess students' self-assessment accuracy before studying. It is, therefore, unclear if students with a poor-quality motivational profile scored worse on self-assessment in general or learned less from the videos. Furthermore, the motivation measure in that study focused on students' motivation to solve the problems on the pretest and posttest, but not for studying the video modeling examples.

Cognitive load in relation to self-assessment accuracy and motivation

One reason why learners are not able to accurately self-assess their performance is that the limitations of working memory hamper them. Self-assessment requires that students construct a mental representation of the task performance process, which requires working memory resources (Kostons et al. 2012). Cognitive load refers to the amount of working memory resources that are devoted to a specific learning situation or task, and is often measured with a subjective estimate of the mental effort invested in learning or performing a task (Paas 1992; Van Gog and Paas 2008). Cognitive load can be determined by the complexity of the learning task (i.e., intrinsic load) or imposed by the ineffective design of the learning material (i.e., extraneous load) or useful for learning (i.e., germane load; Sweller et al. 1998, 2019). New learning tasks often impose a high intrinsic cognitive load on novice learners. Van Gog et al. (2011) showed that learning and self-assessment compete for the same limited working memory resources, which can negatively affect monitoring, task performance, or both when the learning task is new or complex. In these situations, additional monitoring or self-assessment goes beyond the students' working memory capacity and can, therefore, add extraneous cognitive load (see Seufert 2018).

In addition to learning outcomes and self-assessment accuracy, we will, therefore, measure students' mental effort invested while studying the video modeling examples and while solving the heredity problems during the posttest. Students' motivation is rarely taken into account in cognitive load research (Seufert 2018). Although motivation does not affect the objective intrinsic load or complexity of the learning task, mental effort is a subjective rating of cognitive load. Research has shown that the timing of the mental effort rating can affect the ratings, with delayed ratings resulting in higher scores than immediate ratings (Schmeck et al. 2015). Motivation could affect the experience of mental effort as well. For example, it has been shown that autonomous motivation was associated with the feeling of energy (Ryan and Frederick 1997). However, it is unclear whether motivational profiles can affect the subjective experience of mental effort while studying video modeling examples.

Present study and hypotheses

The present study aims to examine the types of motivational profiles students have for studying video modeling examples about heredity problem-solving. We, therefore, investigated whether similar motivational profiles could be identified as in previous educational research, such as good-quality, poor-quality, high-quantity, low-quantity, and moderate motivational profiles (Gillet et al. 2017; Vansteenkiste et al. 2009). In prior research, most studies found between three and six motivational profiles.

Hypothesis 1 We expect that the latent profile analyses will result in three to six motivational profiles.

It is likely that when students experience (relatively) higher levels of autonomous motivation for learning about genetics problem-solving because they perceive this topic as interesting or useful, they will pay better attention to the video modeling examples and learn more from them. Prior research has indicated that profiles characterized by high levels of autonomous motivation, such as the good-quality and high-quantity profiles, and moderate profiles that are characterized by higher levels of autonomous relative to controlled motivation, are more optimal for educational outcomes than poor-quality, low-quantity or moderate profiles with relatively higher levels of controlled than autonomous motivation (see Gillet et al. 2017; Ratelle et al. 2007).

Hypothesis 2 Students with more optimal motivational profiles will score higher on the problem-solving posttest after studying video modeling examples.

Hypothesis 3 Students with more optimal motivational profiles will score higher on the self-assessment accuracy posttest after studying video modeling examples.

In addition to learning outcomes and self-assessment accuracy, we examined whether differences in motivational profiles can also affect subjective mental effort ratings while studying video modeling examples and solving the biology problems during the posttest.

Hypothesis 4 Students' motivational profiles are associated with students' subjective mental effort ratings.

Method

Participants and procedure

First, we recruited schools that were interested in participating in the study. The schools contacted all parents and informed them about the goal and nature of the study. Parental consent was arranged through the schools. The study took place during scheduled class time. During data collection, all responses were anonymized and could not be traced back to the individual students. Participation was voluntary.

Our sample consisted of 342 Dutch secondary school students (52.3% female; $M_{age} = 13.8$, $SD_{age} = 0.72$) in their second or third year of the higher education (i.e., 5-year program) or pre-university educational tracks (i.e., 6-year program) from three schools in the Netherlands (comparable in age to 8th and 9th grades in the United States). Most students ($n = 331$; 96.8%) reported Dutch as the primary language spoken at home, and 5.8% ($n = 20$) of the students self-reported to have been diagnosed with dyslexia.

The study consisted of a one-group pretest-posttest design; the procedure, learning materials, and measures were the same for all students. However, after data collection was concluded, latent profile analyses were conducted to identify naturally occurring subgroups of students with different motivational profiles for studying the topic being taught. The study was conducted in a computer room at the participants' school, in sessions of approximately 50 min each. All measures and materials were presented on the computer. Participants first took a pretest consisting of four problem-solving tasks to test their prior knowledge in heredity problem-solving. Each problem-solving task was followed by a question asking them to self-assess their performance and indicate the amount of mental effort experienced when solving the problem. After the pretest, the studying phase took place, in which students watched an instructional video and four video modeling examples in which the problem-solving task and how to accurately self-assess your performance was modeled. After watching the videos, participants rated the mental effort they experienced while studying the videos and completed a motivation questionnaire. Then the posttest took place, consisting of four problem-solving tasks, and mental effort and self-assessment ratings.

Video modeling examples

In the studying phase, participants watched an instructional video and four video modeling examples. In the instructional video, relevant concepts were explained, such as the difference between homozygote and heterozygote. The difference between deductive (e.g., determining the possible genotypes of the child based on the genotypes of the parents) and inductive (e.g., determining the possible genotypes of one of the parents based on the genotypes of the child and the other parent) reasoning was also explained. After the instructional video, participants watched four video modeling examples in which a human model solved the heredity problem step by step using Mendel's laws. Half of the videos had a male model, the other half a female model. All problems in the video modeling examples concerned deductive reasoning problems.

The first two videos demonstrated how the problems could be solved in five steps: (1) translating the phenotypes described in the cover story into genotypes, (2) constructing a family tree, (3) determining the number of required Punnett Squares by looking at the direction of reasoning (i.e., deductive or inductive), (4) filling out the Punnett Square(s), (5) extracting the final solution from the Punnett Square(s). For each step, the model wrote down the answer while verbally explaining why these steps had to be performed. After solving each problem, the model did a mental effort and self-assessment rating in which the model indicated accurately that he/she had completed all five steps correctly (i.e., 100% self-assessment accuracy score, see Kostons et al. 2012; Raaijmakers et al. 2018).

In the next two video modeling examples, the model made one or more errors. In particular, the model indicated he/she did not remember how to perform a specific step (e.g., not remembering how to fill out the Punnett Square). These videos created variability in the models' self-assessment scores. For example, when the model made one mistake in solving the problem, he/she also produced an accurate self-assessment score of four out of five steps correct. Therefore, the models always had a 100% self-assessment accuracy score.

Measures

Motivation

After studying the video modeling examples, participants filled out a 16-item, situation-specific motivation questionnaire (adapted from Vansteenkiste et al. 2004). The items measured to what extent students studied the videos and problems for external (e.g., "… *because I am supposed to do so*"), introjected (e.g., "… *because I would feel guilty if I did not do it*"), identified (e.g., *"… because I could learn something from it"*), and intrinsic (e.g., "… *because I found it interesting*") reasons. Items responses were on a 4-point Likert-type scale ranging from 1 (*not at all true*) to 4 (*totally true*).

The psychometric properties of the motivation scale were investigated with confirmatory factor analysis in Mplus 8.3 (Muthén and Muthén 2017). Analysis of univariate skewness and kurtosis statistics indicated that these values were in the normal range (Byrne 2012). The assessment of model fit was based on multiple fit indices. The four-factor model had an acceptable fit to the data, $\chi^2(98) = 243.44$, $p < .001$, CFI = .93, TLI = .91, RMSEA = .07, SRMR = .08. A root-mean-square error of approximation (RMSEA) and a standardized root-mean-square residual (SRMR) value of .08 or smaller is acceptable (Byrne 2012;

Steiger 1990). Comparative fit index (CFI; Bentler 1990) and Tucker-Lewis index (TLI; Tucker and Lewis 1973) values greater than .95 are good (Kline 2005), although values above .90 are acceptable (Bentler 1990). All items loaded statistically significantly on the relevant factor ($p < .001$). Reliability analysis resulted in McDonald's ω of .84 for intrinsic motivation, .80 for identified motivation, .66 for introjected motivation, and .64 for external motivation.

Problem-solving pretest and posttest

The pretest and posttest consisted of four heredity problems on Mendel's laws, with four different complexity levels (see Kostons et al. 2012). The posttest included problems that were isomorphic to the pretest problems; that is, they had similar structural features, but the cover stories (i.e., surface features) differed. All problems could be solved in five steps (see description of the five steps above). Three problems concerned deductive reasoning, and one problem covered inductive reasoning. Participants were given three minutes per problem and were asked to complete each of the five steps. Participants' performance was scored by assigning 1 point for each solution step that was performed correctly, resulting in a maximum score of 5 for each problem and a maximum score of 20 for the entire pretest or posttest. Scores were transformed into percentages. The first author coded the answers to all problems; furthermore, four research assistants each coded 25% of the answers with the help of answer key. The intraclass correlation coefficients (ICC) estimate was calculated based on a mean-rating ($k = 2$), one-way random effects model as an indication of interrater reliability (Landers 2015), resulting in an ICC(1) of .923 for the pretest and .911 for the posttest.

Self-assessment accuracy

Participants assessed their performance on each task on a 6-point rating scale ranging from 0 (*none of the steps were correct*) to 5 (*all steps were correct*), assigning one point for each step in the problem-solving process (Kostons et al. 2012). Therefore, the self-assessment ratings and scoring of the problem-solving tasks had the same measurement scale.

Self-assessment accuracy was determined by computing the absolute difference between a student's objective performance score and their self-assessed performance score for each problem (Kostons et al. 2012; Schraw 2009). Lower difference scores indicate higher accuracy (i.e., 0 = 100% accurate). For example, a student with a performance score of 1 but with a self-assessed score of 3 would have a difference score of 2. Each participant's mean self-assessment accuracy score was computed for the pretest and posttest.

Mental effort ratings

After each problem in the pretest and posttest, participants were asked to rate the amount of mental effort they had invested in solving the problem (Paas 1992; Van Gog et al. 2012). Mental effort was rated multiple times because research has shown that letting students rate mental effort after each problem is preferable above having one rating after the entire pre- or posttest (Van Gog et al. 2012). Students rated their perceived mental effort on a 9-point rating scale ranging from 1 (*very, very low mental effort*) to 9 (*very, very high mental effort*). Because we had four mental effort ratings during each test phase (i.e., one rating per problem), we calculated an average score for the pretest as well as the posttest. We also asked students to rate the amount of mental effort they invested in studying the video modeling examples, directly after they watched the last video.

Analyses and results

Latent profile analyses

Latent profile analysis (LPA) was performed in Mplus 8.3 to identify participants' motivational profiles for engaging in the heredity problem-solving tasks. In LPA, individual students are assigned to subgroups based on their observed scores on the four motivation subscales. Based on the number of profiles identified in prior research, we evaluated models including one to six latent profiles using 5000 random sets of start values and 1000 iterations, with the 200 best solutions retained for final stage optimization. In the estimation of the latent profiles, we first started with more flexible models in which variances and means of the four motivation scores (i.e., the profile indicators) were freely estimated in all profiles. However, because this resulted in convergence problems for some of the analyses, we chose a more parsimonious model in which only means of the four motivation scores were freely estimated in all profiles (Morin and Wang 2016; Wang et al. 2016).

Multiple statistical indicators were used to determine the optimal number of profiles in the data, such as the Akaike information criterion (AIC), the consistent AIC (CAIC), the Bayesian information criterion (BIC), the sample-adjusted BIC (ABIC), the adjusted Lo et al.'s (2001) likelihood ratio test (aLMR), and the bootstrap likelihood ratio test (BLRT). These indicators can be used for statistical model comparisons between models with different numbers of classes (Nylund et al. 2007). Lower AIC, CAIC, BIC, and ABIC values indicate better-fitting models. The aLMR and BLRT are tests that compare a k profile model with a k-1 profile model. A significant p value indicates that the model with k profiles fits the data better than the more parsimonious model with one fewer profile (k-1). Simulation studies have shown that the CAIC, BIC, ABIC, and BLRT are particularly effective in choosing a model (Nylund et al. 2007; Peugh and Fan 2013; Yang 2006; see also Morin and Wang 2016). The studies also showed that AIC over-extracts an incorrect number of profiles and aLMR under-extracts them, and are best not used in the class enumeration process. Following Gillet et al. (2017), we report all these indicators but will base the selection of the model on CAIC, BIC, ABIC, and BLRT.

Additionally, we report entropy, smallest class size per profile, and mean class assignment probabilities. Entropy is a summary measure for the quality of the classification in an LPA-model. Values close to 1 indicate good classification accuracy. A cut-off value of .80 can be considered good (Clark and Muthén 2009). Finally, to have an acceptable minimum number of individuals in each profile, we required the smallest profile to include at least 5% of the individuals of the sample (Nylund et al. 2007). Concerning the mean class assignment probabilities for a good profile solution, the mean class assignment probability should be at least .80 (Geiser 2013).

As can be seen in Table 1, the CAIC and BIC decreased when including up to four profiles, but increased again when five profiles were selected. However, the ABIC decreased when including up to 5 profiles, and the BLRT result indicated that the model with an

Table 1 Results from the latent profile analyses

k	LL	#fp	Scaling	AIC	CAIC	BIC	ABIC	Entropy	aLMR	BLRT	Smallest profile	
											n	%
1	−1279.173	8	0.958	2574.346	2613.024	2605.024	2579.647	NA	NA	NA	342	100.00
2	−1168.084	13	2.215	2362.168	2425.020	2412.020	2370.781	.69	.423	< .001	116	33.92
3	−1090.380	18	1.121	2216.760	2303.786	2285.786	2228.686	.81	< .001	< .001	51	14.91
4	−1067.803	23	1.160	2181.606	2292.806	2269.806	2196.845	.79	.175	< .001	30	8.77
5	−1058.135	28	1.135	2172.270	2307.644	2279.644	2190.822	.77	.220	.020	23	6.73
6	−1051.673	33	1.066	2169.346	2328.895	2295.895	2191.212	.78	.266	.320	11	3.22

Note. *LL* = Model log-likelihood; *#fp* = number of free parameters; *AIC* = Akaike information criterion; *CAIC* = consistent AIC; *BIC* = Bayesian information criterion; *ABIC* = sample size-adjusted BIC; *aLMR* = adjusted Lo–Mendell–Rubin likelihood ratio test; *BLRT* = bootstrap likelihood ratio test

Table 2 Mean scores for the four motivational profiles

	Good-Quality Profile ($n = 30$)		Moderately Positive Profile ($n = 134$)		Moderately Negative Profile ($n = 141$)		Poor-Quality Profile ($n = 37$)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(3, 338)$	η^2_p
Intrinsic	3.35_a	0.37	2.44_b	0.43	1.80_c	0.43	1.16_d	0.26	212.91***	.654
Identified	3.54_a	0.24	2.85_b	0.28	2.20_c	0.29	1.22_d	0.27	519.51***	.822
Introjected	2.36_a	0.60	2.22_a	0.47	1.98_b	0.47	1.31_c	0.37	40.50***	.264
External	2.04_a	0.52	2.38_b	0.52	2.81_c	0.45	2.89_c	0.65	31.92***	.221

Scale range = 1–4 (higher scores indicating, more motivation). Mean scores are statistically significantly different based on the Games-Howell procedure post hoc test if they have different subscripts. *** $p < .001$

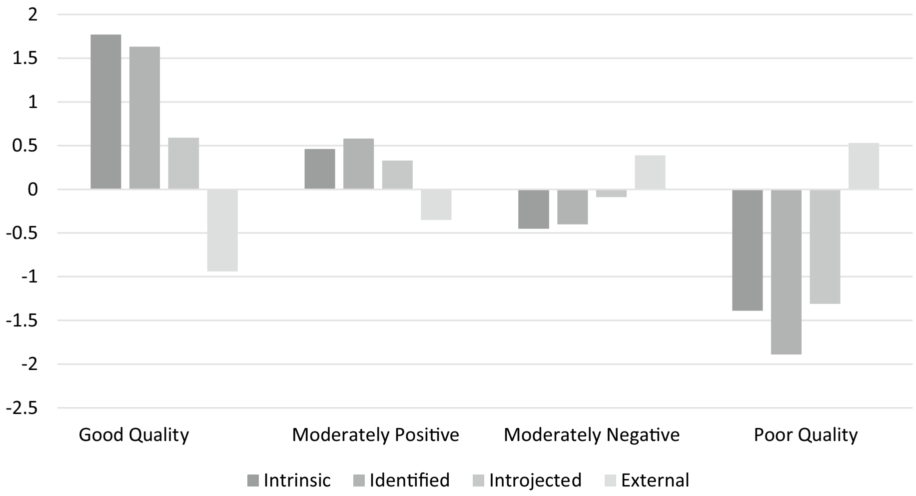

Fig. 1 Standardized means of the four motivational profiles for intrinsic, identified, introjected, and external motivation

additional profile fit the data better than the more parsimonious model with one fewer profile. Based on the results, the 4-profile solution was selected, which supported Hypothesis 1.

Table 2 presents the raw mean scores of the four motivational profiles. Differences between the four profiles were tested with an ANOVA, with the Games-Howell procedure to correct for Type I error. Figure 1 illustrates the standardized mean scores of the four profiles. Scores below −1 indicate low scores, whereas scores above 1 indicate high scores. In our sample, we had class assignment probabilities above .80: Profile 1 (.89), Profile 2 (.85), Profile 3 (.87), Profile 4 (.96). Profile 1 ($n = 30$, 8.77%) was characterized by high scores on intrinsic and identified motivation and moderate scores on introjected and external motivation. This profile was labeled the "good-quality" profile. The good-quality profile was characterized by the highest scores on intrinsic and identified motivation, and lowest scores on external motivation compared to all other profiles.

Profiles 2 ($n = 134$, 39.18%) and 3 ($n = 141$, 41.23%) can both be characterized as moderate motivational profiles. However, students belonging to Profile 2 had statistically significantly higher scores on intrinsic, identified, and introjected motivation and lower scores on external motivation when compared to Profile 3 students. Based on these scores, Profile 2 can best be characterized as a "moderately positive" profile, whereas Profile 3 can best be characterized as a "moderately negative" profile." The students with a moderately positive profile had similar levels of introjected motivation, lower scores on intrinsic and identified motivation, and a higher score on external motivation when compared to the good-quality profile. The students with a moderately negative profile had similar levels of external motivation as the poor-quality profile, but higher scores on intrinsic, identified, and introjected motivation.

Students in Profile 4 ($n = 37$, 10.82%) showed low levels of intrinsic, identified, and introjected motivation and moderate levels of external motivation. Due to their low scores on autonomous motivation combined with a moderate, but highest score on external motivation when compared to the other profiles, we labeled this profile "poor quality".

Differences between motivational profile subgroups

Subsequently, we analyzed differences in the motivational profile subgroups on their learning outcomes on the problem-solving posttest and the self-assessment accuracy posttest, and mental effort during studying and the posttest.

Problem-solving posttest

Table 3 reports the mean scores and standard deviations (*SD*s) for the four motivational profiles on the problem-solving pretest and posttest. Overall, students obtained a mean score of 24.36% correct ($SD = 20.24$) on the pretest and 64.74% correct ($SD = 24.02$) on the posttest, indicating that students improved their performance after studying the video modeling examples. To examine differences between the motivational profile groups, we conducted an ANCOVA with the problem-solving pretest score as the covariate and the

Table 3 Means and SDs for learning outcomes, self-assessment accuracy, and mental effort

	Good-Quality Profile ($n = 30$)		Moderately Positive Profile ($n = 134$)		Moderately Negative Profile ($n = 141$)		Poor-Quality Profile ($n = 37$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Problem-solving pretest	22.50	21.61	24.25	21.27	26.10	19.73	19.59	16.77
Problem-solving posttest	70.67	22.23	69.55	20.37	63.58	25.45	46.89	23.82
Mental effort pretest	6.20	1.76	6.08	2.01	6.02	1.94	6.26	2.67
Mental effort posttest	3.01	1.61	3.52	1.66	3.68	1.90	4.03	2.56
Mental effort studying phase	2.30	1.71	2.69	1.65	3.45	2.30	4.05	3.16
Self-assessment accuracy pretest	1.38	0.80	1.30	0.72	1.32	0.75	1.41	0.95
Self-assessment accuracy posttest	1.18	0.94	1.07	0.70	1.14	0.87	1.69	1.06

Range problem-solving pretest and posttest = 0–100%, range mental effort ratings = 1–9 with a higher score indicating greater effort, range self-assessment accuracy = 0–5 with a higher score indicating less accuracy (0 = perfect accuracy) motivational profile group as the between-subjects factor. To test the statistical assumption that the group and the covariate are independent, we first checked whether the four motivational profile groups differed on the problem-solving pretest, $F(3, 338) = 1.12$, $p = .342$, $\eta^2_p = .010$. The assumption of homogeneity of regression slopes was met. Results of the ANCOVA revealed that the pretest problem-solving score was significantly related to the problem-solving posttest score, $F(1, 337) = 71.90$, $p < .001$, $\eta^2_p = .176$. There were also statistically significant differences in scores on the problem-solving posttest among the different motivational profile groups when taking the pretest score into account, $F(3, 337) = 10.61$, $p < .001$, $\eta^2_p = .086$.

We hypothesized that students with more optimal motivational profiles would score higher on the problem-solving posttest after studying video modeling examples. Based on prior research, the good-quality and moderately positive profiles in our study can be considered more optimal than the moderately negative and poor-quality profiles. To test Hypothesis 2, we conducted planned contrasts for an ANCOVA in SPSS, controlling for the pretest score (see Field 2018), in which students with good-quality and moderately positive profiles were compared with students with poor-quality and moderately negative profiles (Contrast 1). To further specify the results, we also tested whether there was a significant difference between the good-quality and moderately positive groups (Contrast 2) and between the poor-quality and moderately negative groups (Contrast 3). To correct for Type I error, we tested these contrasts using Bonferroni adjusted alpha levels of .017 per test (.05/3). In support of Hypothesis 2, students with good-quality or moderately positive profiles scored significantly higher on the posttest (controlling for the pretest score) than students with poor-quality or moderately negative profiles, $\beta = .31$, $p < .001$, $d = 0.642$. There was no significant difference between the good-quality and moderately positive groups, $\beta = .03$, $p = .646$, $d = 0.065$, indicating that both profiles were equally beneficial for learning to solve the biology problems. However, there was a significant difference between the poor-quality and moderately negative groups, $\beta = .19$, $p = .001$, $d = 0.465$, indicating that the poor-quality group scored significantly worse than the moderately negative group.

Because only deductive reasoning was covered in the video modeling examples and one of the four problems in the pretest and posttest focused on inductive reasoning, we further examined whether similar results were obtained if the deductive problems and inductive problem were analyzed separately. Our analyses revealed a similar pattern of results for separate analysis of the three deductive reasoning problems and the inductive reasoning problem as in our main analysis when all four problems were combined into overall pretest and posttest scores.

Self-assessment accuracy

The means and *SD*s for self-assessment accuracy scores on the pretest and posttest are reported in Table 3. On average, students had a self-assessment accuracy score of 1.33 ($SD = 0.76$) on the pretest and 1.17 ($SD = 0.85$) on the posttest, indicating that students became more accurate in their self-assessment after studying the video modeling examples. To examine differences between the motivational profile groups, we conducted an ANCOVA with self-assessment accuracy on the pretest as the covariate and the motivational profile group as the between-subjects factor. To test the statistical assumption that the group and the covariate are independent, we first checked whether the four motivational profile groups differed on the self-assessment accuracy pretest, $F(3, 338) < 1$, $\eta^2_p = .003$. Furthermore, the assumption of homogeneity of regression slopes was met. Results of the ANCOVA revealed that self-assessment accuracy on the pretest was not statistically significantly related to self-assessment accuracy on the posttest, $F(1, 337) = 2.30$, $p = .131$, $\eta^2_p = .007$. However, there were also statistically significant differences among the motivational profile groups with regard to self-assessment accuracy on the posttest when controlling for the pretest score, $F(3, 337) = 5.28$, $p = .001$, $\eta^2_p = .045$.

To test Hypothesis 3, we examined the same contrasts as for the problem-solving posttest. To correct for Type I error, we tested these contrasts using Bonferroni adjusted alpha levels of .017 per test (.05/3). In support of Hypothesis 3, students with good-quality and moderately positive profiles scored statistically significantly higher on self-assessment accuracy after studying video modeling examples than students with poor-quality and moderately negative profiles, $\beta = -.17$, $p = .014$, $d = 0.338$. The difference between the good-quality and moderately positive groups was not statistically significant, $\beta = .04$, $p = .624$, $d = -0.099$, indicating that both profiles were equally beneficial for learning to self-assess more accurately. There was a significant difference between the poor-quality and moderately negative groups, $\beta = -.21$, $p < .001$, $d = 0.528$, indicating that the poor-quality group scored significantly worse than the moderately negative group on self-assessment accuracy.

Mental effort

Table 3 reports the means and *SD*s of the four motivational profiles for the mental effort ratings. Students' perceived mental effort was measured after each of the problems during the pretest and posttest and after studying the video modeling examples. To examine if motivational profiles were associated with subjective mental effort ratings, an ANOVA and ANCOVA were conducted (Hypothesis 4). Concerning students' mental effort experienced while studying the video modeling examples, an ANOVA indicated statistically significant differences among the motivational profile groups, $F(3, 338) = 6.74$, $p < .001$, $\eta^2_p = .056$. Differences were further explored using the Games-Howell procedure post hoc test. The results indicated that participants with a poor-quality profile indicated that learning the content from the videos was significantly more effortful than participants with a good-quality profile ($p = .027$). A trend emerged showing that students with a poor-quality profile also reported higher mental effort than students with a moderately positive profile ($p = .071$). Furthermore, participants with a moderately negative profile indicated that learning the content was more effortful than participants with a good-quality ($p = .014$) or moderately positive profile ($p = .009$). The difference between students with the good-quality and moderately positive profiles was not statistically significant ($p = .660$), nor was that between the students with poor-quality or moderately negative profiles ($p = .702$).

On average, participants experienced higher mental effort during the pretest ($M = 6.08$, $SD = 2.03$) than on the posttest ($M = 3.60$, $SD = 1.88$). To examine differences between the motivational profile groups, we conducted an ANCOVA with mental effort on the pretest as the covariate and the motivational profile group as the between-subjects factor. To test the statistical assumption that the group and covariate are independent, we first checked whether the four motivational profile groups did not differ on the mental effort pretest, $F(3, 338) < 1$, $\eta^2_p = .001$. Furthermore, the assumption of homogeneity of regression slopes was met. Results of the ANCOVA revealed that mental effort on the pretest was statistically significantly related to mental effort on the posttest, $F(1, 337) = 119.81$, $p < .001$, $\eta^2_p = .262$. However, motivational profile groups did not differ significantly on mental effort on the posttest, taking into account mental effort on the pretest, $F(3, 337) = 2.51$, $p = .059$, $\eta^2_p = .022$.

Discussion

In the present study, we investigated the role of task-specific motivational profiles in learning how to solve heredity problems on Mendel's laws and self-assess their performance in secondary education. Specifically, the current study aimed to investigate whether naturally occurring differences in students' motivational profiles for studying video modeling examples about heredity problem-solving are related to how much students learn from these videos. This study gives insight into whether the variations in learning gains that were found in prior research can be explained by individual differences in students' motivation (Kostons et al. 2012; Raaijmakers et al. 2018).

Situation-specific motivational profiles

Based on prior research we expected that we would identify between three and six motivational profiles (Boiché and Stephan 2014; Gillet et al. 2017; González et al. 2012; Hayenga and Corpus 2010; Kusurkar et al. 2013; Vansteenkiste et al. 2009; Wormington et al. 2012). In support of Hypothesis 1, four motivational profiles were identified: a good-quality, moderately positive, moderately negative, and a poor-quality profile. The good-quality profile was characterized by high levels of autonomous motivation, and moderate introjected and external motivation. Students with a moderately positive profile had statistically significantly higher scores on intrinsic, identified, and introjected motivation and lower scores on external motivation when compared to students with a moderately negative motivational profile. Finally, the poor-quality profile showed moderate levels of external motivation and low levels of autonomous (i.e., intrinsic and identified) and introjected motivation.

Moderate motivational profiles have been identified in several other studies (e.g., Boiché and Stephan 2014; Hill 2013; Ratelle et al. 2007). However, only a few studies made a further distinction between a more positive or autonomous moderate profile and a more controlled or unmotivated moderate profile, similar to our study (Baars and Wijnia 2018; Gillet et al. 2017). In contrast to prior studies, we did not identify a high-quantity or a low-quantity motivational profile (e.g., Boiché and Stephan 2014; Vansteenkiste et al. 2009; Wormington et al. 2012). In all profiles identified in our study, the quality of motivation mattered, in which the good-quality and moderately positive profiles were characterized by relatively higher levels of autonomous and introjected motivation relative to external motivation compared to the poor-quality and moderately negative profiles. Possibly, this is because, in the current study, situation-specific motivational profiles were investigated instead of contextual motivation. Prior research has shown that there is high within-student variability in autonomous and controlled motivation between one learning episode and another, with the variability in autonomous motivation being higher than controlled motivation (Malmberg et al. 2015). The task-specificity of a motivation measure in the current study may reduce the variability in the overall amount of motivation students report, and quality differences in motivation become more pronounced. Situation-specific motivational profiles are rarely investigated in education; however, the results of this study suggest that some of the motivational profiles that are commonly identified on the contextual level may not be identified on the situational level. Further research needs to be conducted to examine whether our results can be replicated in other samples in which situation-specific motivation is measured for a different type of task, in different domains, and different age groups. Knowing more about the how the variability in autonomous motivation is associated with specific learning situations can give teachers more insight into which learning tasks, instructions, and teacher behaviors are most motivating.

Problem-solving and self-assessment accuracy

The main aim of our study was to investigate whether individual differences in students' motivational profiles are related to the extent to which the use of video modeling examples was effective in teaching students how to solve biology problems and self-assess their performance. For problem-solving, we found differences related to the motivational profile group of the students. Contrast analyses revealed that the students assigned to profiles of better motivational quality (i.e., good quality and moderately positive) obtained a higher mean score on the problem-solving posttest than those in the groups with worse motivational quality (i.e., poor quality and moderately negative). Furthermore, the poor-quality group scored significantly lower than the moderately negative group. With respect to self-assessment accuracy on the posttest, similar results were found. When the two higher quality profiles were contrasted with the two lower quality profiles, those in the lower quality profiles were less accurate in self-assessments after studying. Additionally, the poor-quality group had less accurate self-assessment skills after studying the video modeling examples than the moderately negative profile group. These results indicate that individual differences in motivation can be related to the extent to which students learn the correct problem-solving procedure and self-assessment skills by studying video modeling examples. The poor-quality profile, characterized by moderate external motivation combined with low levels of intrinsic, identified, and introjected motivation, was especially associated with poorer posttest performance and self-assessment accuracy after studying. The results from our study further suggest that at least moderate or high intrinsic and identified task motivation is necessary for promoting self-assessment skills in order to buffer the deleterious effects of external motivation (see Gillet et al. 2017). Our results are in line with earlier studies that found that moderate profiles with relatively higher levels of autonomous motivation and good-quality profiles are both beneficial for educational outcomes.

In the current study, moderate levels of introjected motivation were not associated with lower levels of problem-solving performance and self-assessment accuracy. This may seem unexpected, because introjected motivation is a controlled type of motivation and has been negatively associated with academic achievement (Taylor et al. 2014). However, as mentioned, controlled types of motivation are not always associated with poorer learning and achievement outcomes if they co-occur with higher levels of autonomous motivation (Gillet et al. 2017; Wormington et al. 2012). Furthermore, in physical education, moderate levels of introjected motivation were associated with better achievement (Boiché et al. 2008). In addition, Pelletier et al. (2001) found that introjected motivation was positively associated with persistence over a period of 1 year in athletes, but became nonsignificant over a longer period. In our study, we only examined the role of motivational profiles during one 50-min lesson. If introjected motivation can facilitate persistence on the short-term (Pelletier et al. 2001), this explains why moderate levels of introjected motivation can have short-term benefits for studying video modeling examples.

Additionally, some researchers have made a distinction between positive (approach) and negative (avoidance) forms of introjected motivation, in which positive introjection falls between identified motivation and negative introjection on the self-determination continuum (Assor et al. 2009; Sheldon et al. 2017). Furthermore, Assor et al. (2009) showed that negative introjection was associated with more negative affective and performance outcomes than positive introjection. In the motivation measure used in our study, two items could be classified as negative introjection and two as positive introjection. In future research, negative as well as positive introjection could be examined in more detail in latent profile analyses to determine how introjected motivation is related to (short-term) engagement and learning outcomes.

Experimental research has shown that video modeling examples are an effective form of instruction for novice learners who are in the early stages of skill acquisition for various types of tasks, such as problem-solving and self-assessment skills (see Kostons et al. 2012; Van Gog and Rummel 2010; Van Gog et al. 2019). However, in research on designing effective instructional methods, such as video modeling examples, the motivation of the learner is often not taken into account (cf. Seufert 2018). Overall, our results demonstrated that individual differences in students' motivational profiles could be associated with the extent to which students learn from watching video modeling examples. The results imply that the effectiveness of video modeling examples might be further improved if the motivation for studying them is considered as well. During the data collection for this study, some participants indicated that they experienced the videos as boring, which suggests there is room for improvement. Although research has examined different guidelines to make video modeling examples more effective and efficient for learning, such as seeing the face of a human model and taking into account the gender and age of the model and learner (e.g., Hoogerheide, Van Wermeskerken et al. 2016; Van Gog et al. 2014), our results indicate that it is important to combine guidelines for effective and efficient instruction with strategies to make the videos more interesting and autonomously motivating.

Mental effort

In addition to learning outcomes and self-assessment accuracy, students' perceived mental effort was explored. Mental effort is a self-reported measure of cognitive load (Paas 1992). As mentioned, cognitive load research often does not take motivation measures into account (Seufert 2018). We did not find differences between the four motivational profile groups on the mental effort experienced during the posttest phase. However, the results of our study suggest that the students with poor-quality or moderately negative profiles experienced watching the video modeling examples as more effortful than students with good-quality or moderately positive profiles. Although motivation does not affect the complexity of the learning task or intrinsic load of studying the videos, we assume that motivation could affect the experience of cognitive load. Prior research has indicated that autonomous motivation can have an energizing effect on people (Pelletier and Rocchi 2016; Ryan and Frederick 1997); thus, it is possible that students with motivational profiles characterized by higher levels of autonomous motivation experienced lower mental effort during the studying phase, due to an energizing effect of autonomous motivation. For example, more optimal motivational profiles have been associated with less experience of burnout for teachers (e.g., emotional exhaustion; Van den Berghe et al. 2013; Van den Berghe et al. 2014). In future studies, this could be examined by including measures of subjective vitality or the amount of energy the students experienced themselves to have available, in addition to mental effort and motivational profiles.

Limitations and future research

A limitation of the current study is the limited sample size. Another limitation is that we did not measure amotivation. In some prior studies on motivational profiles, amotivation was measured in addition to intrinsic, identified, introjected, and external motivation (Gillet et al. 2017). Because amotivation usually tracks with the levels of controlled motivation in the good and poor-quality profiles, we assume that amotivation would have tracked with the levels of external motivation in the current sample. Nevertheless, it would be interesting to see if similar situation-specific profiles emerge if all motivational facets from SDT are included in the analyses. Another limitation is that the introjected and external motivation scales had low reliabilities in our study, which could have affected our results. Although we used an existing task-specific measure, some items might not have functioned optimally. In future studies, we could examine how we can adapt the scale to suit the context of the current study. A distinction between positive and negative introjection might also improve the scale.

Future research could examine if the effectiveness of video modeling examples could be further optimized by combining video modeling with a motivation intervention. According to SDT, the learning environment can support students' motivation and subsequent learning by being autonomy-supportive (Deci and Ryan 2000; Ryan and Deci 2000; Vansteenkiste et al. 2004). Autonomy support can be achieved by showing respect, offering students a certain degree of choice in learning materials, communicating why (uninteresting) study activities are relevant for students' goals, and using noncontrolling language (Assor et al. 2002; Black and Deci 2000; Katz and Assor 2007; Vansteenkiste et al. 2004; Vansteenkiste et al. 2005). Future research could examine the role of these elements in video modeling examples, in combination with guidelines to optimize learning from video modeling examples as well as the learner's motivation.

As mentioned, prior research has indicated that adult learners, as well as children often make inaccurate judgments and make self-assessment errors (e.g., Koriat and Shitzer-Reichert 2002; Lipko et al. 2009; Rawson and Dunlosky 2007). Video modeling examples have been shown to be effective to improve self-assessment accuracy (Kostons et al. 2012; Raaijmakers et al. 2018). However, most studies have examined the effectiveness of video modeling examples in the context of biology problem-solving in secondary education. Research suggests that skills learned through video modeling could transfer to another task (Raaijmakers et al. 2018). Possibly, situation-specific motivational profiles could affect the extent to which learners can transfer the learned skills to other domains. More research is needed to examine the role of situation-specific motivational profiles in the effectiveness of video modeling to learn self-assessment skills or metacognitive skills in the context of different learning tasks and different age groups.

Furthermore, it could be interesting to include other measures of cognitive load. Perceived task difficulty has been used as an indicator of cognitive load as well. Mental effort and perceived task difficulty are related but different constructs. Invested mental effort refers to a process and involves more aspects than only the task, whereas perceived task difficulty is mainly focused on the task (Van Gog and Paas 2012). It would be interesting to investigate how motivational profiles are associated with perceptions of task difficulty. Possibly, students with poor-quality and moderately negative profiles experience the learning task as more difficult than students with good-quality or moderately positive profiles. If students experience the task as too difficult, their need for competence is not satisfied, which could lead to lower levels of autonomous motivation (Deci and Ryan 2000).

Conclusion and implications

In summary, the current study examined the relation of situation-specific motivational profiles from a self-determination perspective with problem-solving performance, self-assessment accuracy, and mental effort *after* studying self-assessment video modeling examples. Although the video modeling examples have been shown to be generally effective in promoting learning and self-assessment accuracy and reducing mental effort (see Kostons et al. 2012), our results show that the quality of students' motivation can affect the extent to which video modeling examples are beneficial. Specifically, the results indicate that students with motivational profiles higher in quality (i.e., good-quality and moderately positive profile) obtain higher scores on the problem-solving posttest and self-assessment accuracy when compared to students with lower quality of motivation (i.e., poor-quality and moderately negative profiles). Especially, having a poor-quality motivational profile, characterized by moderate external motivation combined with low levels of intrinsic, identified, and introjected motivation, was related to poorer posttest performance and self-assessment accuracy after studying video modeling examples. Furthermore, students characterized by profiles lower in motivational quality (i.e., poor-quality and moderately negative profiles) experienced the studying phase as more effortful. For video modeling examples to have the best effects on learning, it is therefore important to consider students' motivation for learning the content of the videos and to examine whether good-quality or moderately positive profiles can be further promoted through interventions.

Appendix A: Prior research on motivational profiles in education

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
1a-b.	Baars and Wijnia (2018): S1 and S2	Situation-specific motivation toward solving biology problems (A-SRQ): intrinsic, identified, introjected, and external motivation	8th–9th grade students	LPA	4	"Good quality" (14.05% S1; 10.39% S2): highest levels of intrinsic and identified, the lowest level of external.	Good quality
						"Poor quality" (17.98% S1; 32.47% S2): highest levels of external, lower scores on intrinsic, identified, introjected.	Poor quality
						"Moderately positive" (32.02% S1; 29.87% S2): relatively moderate scores, but intrinsic and identified scores were higher than the other moderate profile.	Moderate
						"Moderately negative" (35.96% S1; 27.27% S2): relatively moderate scores, but higher on external than the other moderate profile.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
2.	Boiché and Stephan (2014)	Contextual motivation toward college (AMS): intrinsic, identified, introjected, external, and amotivation	1st year undergraduate science program students	CA	5	"Self-determined" (20%): above-average intrinsic and identified; below-average introjected; low external and amotivation.	Good quality
						"Non-self-determined" (9%): below-average intrinsic and identified; above-average introjected; high external and amotivation.	Poor quality
						"Additive" (30%): high levels of intrinsic and extrinsic motivation; below-average amotivation.	High quantity
						"Low" (17%): low quantity motivation; average amotivation.	Low quantity
						"Moderate" (24%): above-average identified and external; below-average intrinsic, introjected, and amotivation.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
3.	Cannard et al. (2016)	Contextual motivation toward college (AMS): intrinsic, identified, introjected, external, and amotivation	Undergraduate students	CA	5	"Intrinsic" (17.00%): high intrinsic; low introjected and external; low amotivation.	Good quality
						"Combined" (30.20%): high quantity of motivation; low amotivation.	High quantity
						"Demotivated" (12.90%): low quantity of motivation and amotivation.	Low quantity
						"Amotivated" (15.50%): low intrinsic and identified; high amotivation.	Low quantity
						"Extrinsic" (24.40%): high extrinsic; low intrinsic and amotivation.	Other
4.	Cents-Boonstra et al. (2019)	Contextual motivation toward studying (A-SRQ): intrinsic, identified, introjected, and external motivation	VET students (16+ years old)	LPA	4	"High quality" (25%): relatively high intrinsic and identified, relatively low introjected and external.	Good quality
						"Low quality" (41%): relatively low intrinsic and identified, relatively high introjected and external.	Poor quality
						"High quantity" (27%): relatively high on all subscales.	High quantity
						"Low quantity" (7%): relatively low on all subscales.	Low quantity

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
5.	Corpus and Wormington (2014)	Contextual motivation toward school: intrinsic and extrinsic motivation	3rd-5th grade (fall measure)	CA	3	"Primarily intrinsic" (33.67%): relatively high intrinsic and low extrinsic motivation.	Good quality
						"Primarily extrinsic" (33.67%): relatively high extrinsic and low intrinsic motivation.	Poor quality
						"High quantity" (32.65%): high extrinsic and intrinsic.	High quantity

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
6a-b.	Ganotice et al. (2020): S1 and S2	Contextual motivation toward studying (A-SRQ): autonomous and controlled motivation	S1: 1st-4th year college students S2: high school students	CA	4	"High autonomous-low controlled" (20.90% S1; 16.50% S2): high autonomous, low controlled motivation.	Good quality
						"High autonomous-high controlled" (23.20% S1; 63.20% S2): high autonomous and controlled motivation.	High quantity
						"Low autonomous-low controlled" (17.60% S1; 6.80% S2): low autonomous and controlled motivation.	Low quantity
						"Moderate autonomous-moderate controlled" (38.20% S1; 13.50% S2): average/moderate autonomous and controlled motivation.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
7.	Gillet et al. (2017)	Contextual motivation toward studying (A-SRQ): intrinsic, identified, introjected, external, and amotivation	1st year undergraduate psychology students	LPA	6	"Autonomous" (10.00%): high intrinsic and identified; average introjected and external; low amotivation.	Good quality
						"Controlled" (15.80%): low intrinsic and identified; high amotivation; high introjected and external.	Poor quality
						"Strongly motivated" (29.00%): moderately high quantity of motivation; average amotivation.	High quantity
						"Poorly motivated" (8.10%): high amotivation; low intrinsic and identified; low introjected and external.	Low quantity
						"Moderately autonomous" (16.00%): moderately high intrinsic and identified; low introjected, external, and amotivation.	Moderate
						"Moderately unmotivated" (21.10%): moderately low intrinsic and identified; average introjected and external; moderately high amotivation.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
8.	González et al. (2012)	Contextual motivation toward university: intrinsic, identified, introjected, external, and amotivation	Undergraduate students	CA	4	"Autonomous" (35.00%): low amotivation, external, and introjected; high identified and intrinsic.	Good quality
						"Controlled" (19.00%): high external; moderately high introjected and amotivation; low intrinsic and identified.	Poor quality
						"High autonomous and controlled" (30.00%): high external, introjected, identified, and intrinsic; moderately high amotivation.	High quantity
						"Low autonomous and controlled" (16.00%): low quantity of motivation; moderately high amotivation.	Low quantity
9.	Hayenga and Corpus (2010)	Contextual motivation toward school: intrinsic and extrinsic motivation	6th–8th grade students	CA	4	"Good quality" (19.24%): high intrinsic and low extrinsic.	Good quality
						"Poor quality" (19.53%): low intrinsic and high extrinsic.	Poor quality
						"High quantity" (32.65%): high intrinsic and extrinsic.	High quantity
						"Low quantity" (28.57%): low intrinsic and extrinsic.	Low quantity

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
10a-b.	Hill (2013): S1 and S2	Contextual motivation toward university (AMS): intrinsic to know, intrinsic for accomplishment, intrinsic for stimulation, identified, introjected, external, and amotivation	1st year undergraduate students in sports-related programs	CA	3	"Low autonomous, moderate controlled, and moderate amotivation" (18% S1; 28% S2): lowest levels of intrinsic; low levels of identified and introjected, similar external, highest levels of amotivation.	Poor quality
						"High autonomous, high controlled, and low amotivation" (51% S1; 15% S2): highest levels of intrinsic, identified and introjected motivation; high external, low amotivation.	High quantity
						"Moderate autonomous, moderate controlled, and low amotivation" (31% S1; 57% S2): Scores in between the other profiles.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
11.	Kong and Liu (2020)	Contextual motivation toward school (AMS): intrinsic, identified, introjected, external, and amotivation	9th grade	CA	3	"Unmotivated" (43.33%): high amotivation, moderate external and introjected, low identified and intrinsic regulation.	Poor quality
						"Highly motivated" (33.33%): moderate amotivation and external; high introjected, identified, and intrinsic.	High quantity
						"Moderate-autonomous" (26.67%): low amotivation, external, and introjected; moderate identified and intrinsic.	Moderate
12.	Kusurkar et al. (2013)	Contextual motivation toward college (AMS): intrinsic and controlled motivation	1st-6th year medical students	CA	4	"Interest-motivated" (26.10%): high intrinsic; low controlled.	Good quality
						"Status-motivated" (31.80%): low intrinsic; high controlled.	Poor quality
						"Interest + status motivated" (25.20%): high intrinsic; high controlled.	High quantity
						"Low-motivation" (16.90%): low intrinsic; low controlled.	Low quantity

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
13.	Litalien et al. (2019)	Contextual motivation toward college (AMS): intrinsic to know, intrinsic for accomplishment, intrinsic for stimulation, identified, introjected, external, and amotivation	Undergraduate students	LPA	5	"Controlled" (26.00%): moderately high external and introjected, moderately low amotivation, average intrinsic motivations and identified.	Poor quality
						"Multifaceted" (15.00%): low amotivation, average intrinsic motivation to experience stimulation, other types high.	High quantity
						"Unmotivated" (25.40%): high amotivation, average intrinsic motivation to experience stimulation, other types low.	Low quantity
						"Knowledge-oriented" (17.60%); moderately high levels of intrinsic motivation to know, low amotivation, average other types.	Moderate
						"Hedonist" (16.00%): high intrinsic motivation to experience stimulation and amotivation, moderately high identified, low introjected, average other types.	Other

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
14.	Oga-Baldwin and Fryer (2018)	Course-specific motivation for learning English (A-SRQ): intrinsic, identified, introjected, and external motivation	5th–6th grade students (Time 1)	LPA	3	"Good quality" (52.05%): relatively higher autonomous than controlled motivation.	Good quality
						"Poor quality" (11.70%): relatively low autonomous motivation compared to high controlled motivation.	Poor quality
						"High quantity" (36.26%): relatively high autonomous and controlled motivation.	High quantity
15.	Oga-Baldwin and Fryer (2020)	Course-specific motivation for learning English and Japenese (A-SRQ): intrinsic, identified, introjected, and external motivation	7th grade students	LPA	5	"Good quality": higher autonomous than controlled.	Good quality
						"Poor quality": relatively low autonomous compared to controlled motivation.	Poor quality
						"High quantity": above-average controlled and autonomous motivation.	High quantity
						"Low quantity": low autonomous and controlled motivation.	Low quantity
						"Moderate motivation": autonomous and controlled motivation around sample mean.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
16.	Pugh (2019)	Contextual motivation toward college (AMS): intrinsic to know, intrinsic for accomplishment, intrinsic for stimulation, identified, introjected, external, and amotivation	Undergraduate students	CA	2	"Internally motivated" (31.60%): higher levels of all motivation types, expect amotivation.	High quantity
						"Low quantity – externally motivated" (68.40%): lower levels of all motivation types.	Low quantity
17a-b.	Ratelle et al. (2007): S1 and S2	Contextual motivation toward school (AMS): intrinsic, identified, introjected, external, and amotivation	High school students	Other	3	"Controlled" (5.90% S1; 7.30% S2): low autonomous; moderate to high controlled and amotivation.	Poor quality
						"High autonomous and controlled" (48.20% S1; 33.30% S2): high autonomous and controlled; low amotivation.	High quantity
						"Moderate autonomous and controlled" (45.90% S1; 59.40% S2): moderate autonomous and controlled; low amotivation.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
17c.	Ratelle et al. (2007): S3	Contextual motivation toward college (AMS): intrinsic, identified, introjected, external, and amotivation	1st year college students	Other	3	"Truly autonomous" (36.30%): high autonomous; low controlled and amotivation.	Good quality
						"High autonomous and controlled" (38.60%): high autonomous and controlled; low amotivation.	High quantity
						"Low autonomous and controlled" (25.10%): low autonomous and controlled; high amotivation.	Low quantity
18.	Vanslambrouck et al. (2018)	Contextual motivation toward college (AMS): intrinsic, identified, introjected, external, and amotivation	Students in a teacher education program	CA	3	"Self-determined" (27%): high intrinsic, above neutral identified, low introjected, external and amotivation.	Good quality
						"Additive" (52%): high intrinsic and identified, neutral introjected and external, low amotivation.	High quantity
						"Moderate" (21%): above neutral identified and external, below neutral intrinsic motivation, low introjected and amotivation.	Moderate

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
19a-b.	Vansteenkiste et al. (2009): S1 and S2	S1: Contextual motivation toward studying (A-SRQ): autonomous and controlled motivation S2: Course-specific motivation (A-SRQ): autonomous and controlled motivation	S1: 7th–12th grade students S2: 1st year teacher training students	CA	4	"Good quality" (18% S1; 23% S2): high autonomous; low controlled.	Good quality
						"Poor quality" (27% S1; 19% S2): high controlled; low autonomous.	Poor quality
						"High quantity (27% S1; 22% S2): high autonomous and controlled.	High quantity
						"Low quantity" (28% S1; 35% S2): low autonomous and controlled.	Low quantity
20.	Wang et al. (2017)	Course-specific motivation toward math class (A-SRQ): intrinsic, identified, introjected, and external motivation.	Secondary school students	LPA	4	"High in identified and intrinsic motivation" (50.7%).	Good quality
						"Very low levels of introjected, identified, and intrinsic regulation" (5.8%).	Low quantity
						"Low identified and intrinsic motivation" (33.2%): with moderately low external and introjected.	Moderate
						"High external, high identified, and low intrinsic motivation" (10.2%).	Other

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
21.	Wormington et al. (2012)	Contextual motivation toward school (AMS): intrinsic, introjected, and external motivation	High school students	CA	4	"Good quality" (19.54%): relatively higher scores on intrinsic than introjected and external, but lower than the high quantity profile.	Good quality
						"Poor quality" (26.47%): relatively higher scores on external than on intrinsic and identified.	Poor quality
						"High quantity" (42.83%): highest scores on motivation.	High quantity
						"Low quantity with poor quality" (11.16%): low scores on intrinsic and introjected and relatively high scores on external.	Low quantity

Article		Type of motivation	Sample	Method	#	Description of profiles	Label
22.	Zhang and Lin (2020)	Course-specific motivation: intrinsic, identified, introjected, and external motivation	Virtual middle and high school students	CA	4	"Good quality" (29.20%): relatively high autonomous; relatively low controlled motivation.	Good quality
						"Poor quality" (28.50%): high levels of external, low levels of other motivational types.	Poor quality
						"High quantity" (19.70%): high scores on motivation.	High quantity
						"Low quantity" (22.50%): low scores on motivation.	Low quantity

Note. S = Study, *AMS* = Academic Motivation Scale, *A-SRQ* = Academic Self-Regulation Questionnaire, *VET* = vocational education and training, *LPA* = latent profile analysis, *CA* = cluster analysis, # = number of profiles identified,. The overview was based on a literature search of the Web of Science Core Collection using the search terms "self-determination theory" AND "profile" OR "cluster". Date last searched June 17, 2020

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Related reports This study was previously presented at the 7th International Self-Determination Theory Conference:

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Compliance with ethical standards

Ethical approval Data were collected in 2017 in the context of a bachelor's thesis project under the guidelines of the ethical committee of the Department of Psychology, Education and Child Studies, Erasmus University Rotterdam. Participating students and researchers filled out and submitted an ethics checklist. The study was exempt from further ethical approval procedures because the materials and procedures were not invasive. Participation in the study was voluntary. Parents/legal guardians gave informed consent.

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