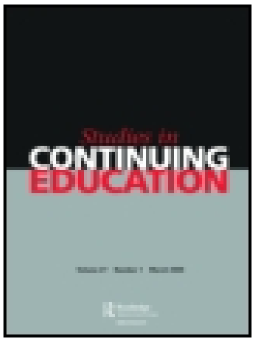

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Occurrences and quality of teacher and student strategies for self-regulated learning in hands-on simulations

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For many decades, teacher-structured hands-on simulations have been used in education mainly for developing procedural and technical skills. Stimulating contemporary learning outcomes suggests more constructivist approaches. The aim of this study is to examine how self-regulated learning (SRL), an important constructivist learning environment characteristic, is expressed in hands-on simulations. Via structured observations of teachers' SRL promoting strategies and students' SRL strategies in eight hands-on simulations, along the three phases of SRL, this study is the first to expose whether students and teachers use SRL in hands-on simulations, what these strategies look like and what their quality is. The results show that both students and teachers demonstrate SRL behaviour in the forethought, performance and reflection phase to some extent, but that they vary considerably in their occurrences, form and quality and provide opportunities for improvement. For example, teacher strategies 'modelling' and 'scaffolding' were often used, while 'giving attribution feedback' and 'evaluation' were lacking. The student strategy 'proposing methods for task performance' was used regularly, while 'goal-setting' and 'self-monitoring' were often absent. An overview shows exemplary teacher and student behaviours in the SRL phases with lower, medium and higher quality in hands-on simulations.

Keywords: self-regulated learning; vocational education; situated learning; simulated learning

Introduction

Intentions in vocational and professional bachelors' degree education have shifted from developing technical skills to developing lifelong learning skills, such as competencies and professional identity (Wesselink et al. 2007). Innovations in vocational curricula to accomplish this have taken concrete forms, such as using realistic tasks and learning environments aiming at that integrate knowledge, skills and attitudes (De Bruijn 2012; Sturing et al. 2011).

A direct consequence is that learning environments situated in the working context, such as *hands-on simulations*, are increasingly used in vocational and professional bachelors' degree education (Billett 2012; Rush et al. 2010). In educational simulations, the vocational context and tasks are replicated in either a virtual or live environment (Hertel and Millis 2002). The simulations in this paper are 'hands-on'. Meaning that the

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students learn by performing one or more professional tasks 'live' in a learning setting that is a realistic replica of the workplace context, with tangible material and equipment (Khaled et al. 2014). These simulations were traditionally used for acquisition of procedural and technical knowledge and skills that students need before entering the workplace and that require equipment and expertise not available in regular educational settings and/or involve risk of injuring or harming the environment (Bell and Waag 1998; Kneebone et al. 2007). The hands-on simulations in our study are part of innovative vocational curricula aiming at a range of (new) learning outcomes that required integrating knowledge, skills and attitudes for professional competence such as problem-solving, customer services, communication and cooperating. As such, the learning environment characteristics of these new hands-on simulations are expected to be different than the more 'traditional' hands-on simulations.

For many years, it was common practice to use more 'traditional' didactic approaches in hands-on simulations: learning by doing and learning from feedback for procedural and technical skills development (Cunningham 1984) within a completely teacher-provided structure (Maxwell, Mergendoller, and Bellisimo 2004). Now that vocational curricula aim at developing not only knowledge and skills, but also professional competence, one might question whether the 'traditional' approach to hands-on simulations is sufficient or whether more constructivist, pedagogical-didactic approaches to teaching and student learning are required (Khaled et al. 2014).

Constructivist learning theory and self-regulated learning

The ultimate aim of vocational education is to develop profession-specific skills and more general competencies to prepare students for their role as professionals capable of performing their job, continue to develop their competencies, and are able to anticipate future developments in their professional field (Biemans et al. 2009). This requires practice and professional experience, learning how to deal with complex situations; moreover it requires students to become independent and self-directed thinkers. Innovative vocational education aims at stimulating developing new learning outcomes, like competencies or improved transfer of learning to the workplace. Many innovations in vocational education introduce constructivist learning environments to foster these learning outcomes. They stimulate active participation of students towards deeper learning necessary for competence development (Baeten, Struyven, and Dochy 2013) and for building relationships between pieces of knowledge, skills and attitudes necessary for transferring classroom learning to the workplace (Baartman and De Bruijn 2011). Active learning requires students to take agency or ownership of their own learning, in other words adopt self-regulation strategies (Boekaerts 1999; Zimmerman 1990). Self-regulated learning (SRL) refers to the executive aspects of metacognition, such as self-awareness, monitoring and regulation of cognitive processes for task performance (Volet, Vauras, and Salonen 2009). To be more concrete, in the process of SRL, students have ownership over their learning by planning, monitoring and managing their learning (Pintrich 1995; Winne and Hadwin 1998; Zimmerman 2001). SRL can occur in the forms of self-controlling how long a student wants to work on a task, choosing whether or not to restudy a task, choosing what information to study or choosing what task to work on (Kostons, Van Gog, and Paas 2012).

An important notion is that SRL can be seen as a goal in itself, i.e., becoming a self-regulated learner (Zimmerman 2002), which is an important goal of many educational innovations nowadays. However, self-regulation can also be approached as a means to acquire other goals, like the development of competencies (Boekaerts and Cascallar 2006). This study focuses on the latter; we study hands-on simulations as part of educational curricula aiming at stimulating competency development. In innovative vocational education, authentic learning environments that explicitly stimulate employing self-regulatory learning strategies are theorised to be needed for actually fostering the development of competencies and lifelong learning (De Bruijn and Leeman 2011). This study examines whether and how hands-on simulations indeed promote the use of self-regulatory learning strategies by teachers and students, based on the idea that if they do so, they in turn foster competency development and thus transfer from training to job. Since students often encounter workplace contexts for the first time in a hands-on simulation, these learning environments are the perfect place to experiment with guiding their own learning as required in the real workplace.

Up till now, most empirical studies on SRL have been conducted in primary, secondary and university educational contexts, and very little research has been conducted on SRL in vocational education contexts (Berger 2012), especially not in hands-on simulations. Although hands-on simulations are often part of an innovative vocational education programme that stimulates SRL, research on SRL in hands-on simulations is still in its infancy. Very little has been reported about how teachers and students have picked up SRL in hands-on simulations; we do not know whether and how teachers stimulate SRL in simulations and whether and how students show SRL behaviours in hands-on simulations. More insight into these processes is required before we can study whether and how SRL affects performance in hands-on simulations and helps to foster competence development (Jossberger et al. 2010). Yet some studies regarding SRL in hands-on simulations were found.

SRL in hands-on simulations

The main challenge for teachers is to create a balance between teacher guidance and students' SRL in hands-on simulations. Jossberger et al. (2010) found that students feel the need for teachers to be constantly present during hands-on simulations and guide their learning closely. At the same time, teachers feel that it is difficult to be constantly around since students do not always work in one room during the simulation. Jossberger et al. (2010) also found that important self-regulatory activities, such as choosing what task to perform, planning and reflection, were poorly integrated in various hands-on simulations across different vocational educational programmes, while one of the most important requirements of the simulations in this study was self-regulated performance of professional tasks.

In clinical education, a first step in empirical research on SRL in hands-on simulations has been taken. The studies by Brydges (Brydges, Carnahan, Rose, et al. 2010; Brydges, Carnahan, Safir, et al. 2009) not only show that hands-on simulations can be appropriate learning settings for SRL with the aim of improving clinical technical skills, but also show that teacher guidance is needed to some extent. Brydges, Carnahan, Rose, et al. 2010; Brydges, Carnahan, Safir, et al. 2009 examined clinical simulations in which he compared teacher-structured simulations to self-regulated forms of learning. Brydges showed that SRL can lead to better clinical performance, but only when the students work on progress goals and when their learning is being monitored. Medical students who had clear progress goals to work on were capable of self-guiding their access to instruction in hands-on simulations (Brydges, Carnahan, Safir, et al. 2009). This self-guidance had a positive effect on learning compared to hands-on simulations in which the instruction was externally controlled.

However, the studies described took place in more controlled research settings and mainly in the medical and nursing domains. No empirical studies on SRL in hands-on simulations in other domains and related to other learning outcomes (such as more general competencies) were found. Also, most of the existing research defines SRL as an aptitude or personal characteristic (i.e., ability to be self-regulative) and mostly rely on survey methods to investigate SRL rather than investigating what students and teachers *actually do* to stimulate SRL in a specific educational context (Patrick and Middleton 2002; Perry 2002). Therefore, the present study uses structured and theoretically grounded observations to examine whether and how teachers promote SRL and whether and how students use SRL strategies in hands-on simulations across various domains in the life-sciences that all aim at competence development. Zimmerman (2001) and Schunk (2001) describe the sub-processes of SRL in three phases: forethought, performance control and self-reflection. These provide the theoretical framework for examining SRL in this study (Table 1).

In sum, hands-on simulations have traditionally been completely teacher-structured. For competence development (the main aim of vocational education), another approach might be more suitable, i.e., constructivist learning including SRL. Since 2010, innovations in vocational education are based on an outcome-based (i.e., competence-based) qualification framework that resulted in educational innovations that pay attention to principles of competence-based education (Sturing et al. 2011), stimulating SRL takes an essential place. Because of this, one might assume that also teachers in hands-on simulations might have picked up these principles and introduced them, to at least some extent, in hands-on simulation. However, empirical evidence is lacking regarding SRL in hands-on simulations. Before we can further examine the effects of SRL in hands-on simulations, we have to gain insight into whether SRL has a place in hands-on simulations and precisely how this looks. Insights into the occurrence and quality of SRL strategies in hands-on simulations will provide implications for teachers on how to better facilitate SRL during the three phases. Also, this study will set the stage for further research on the effect that SRL hands-on simulations have on outcomes such as competencies. The research questions are:

(1) To what extent do teachers show the various SRL promoting behaviours in hands-on simulations?
(2) To what extent do students show the various SRL behaviours in hands-on simulations?
(3) What is the quality of the teachers' SRL promoting strategies and students' SRL strategies in the three phases, and how do teachers' and students' SRL behaviours look in the three phases with lower, medium and higher quality?

Methods

From 2010 to 2012, eight hands-on simulations – as part of vocational education curricula in the life-sciences – were observed as they are, in their naturalistic setting, without interference or interventions from researchers (Table 2). The hands-on simulations were off school campus and functioned as a practical part of the formal curriculum.

Table 1. Teacher strategies for stimulating SRL and student strategies for SRL in the forethought, performance and self-reflection phase of Zimmerman (2001).

Phase	Strategy
Forethought	Teacher – Gets students to choose what tasks to perform and choose how to perform them (Loyens, Magda, and Rikers 2008) and models desired behaviour (Schunk 2001)
	Students – Set goals by planning how they are going to achieve them, and planning what resources they need for successful completion and proposing methods/approaches for task completion (Hattie 2009; Pintrich 2000)
Performance control	Teacher – Gives attributional feedback (linking prior achievements to the students' effort; Schunk 2001) – Verbalises process steps, problem-solving strategies and self-regulatory strategies (Lunenberg, Korthagen, and Swennen 2007) – Gives hints and cues (coaching; Collins, Brown, and Holum 1991) – Supports students with help or additional materials or resources (scaffolding; Collins, Brown, and Holum 1991)
	Students – Ask for feedback (Hattie 2009) – Explicitly verbalise steps in problem-solving and how to proceed (Hattie 2009) – Seek help for problem-solving (Brookfield 2009)
Self-reflection	Teacher – Gives progress feedback (Hattie and Timperley 2007; Schunk 2001) – Evaluates performance and learning progress (Schunk 2001)
	Students – Monitor their own performance and learning progress (Winne and Hadwin 1998) – Self-evaluate learning outcome (Schunk 2001)

The hands-on simulations in this study are characterised as follows: (1) the learning settings were *simulations* of workplace contexts and professional tasks; (2) the simulations were *practical* and hands-on (working on tasks in a real-life setting with tangible material and equipment); (3) the aim was to *train* students for vocational-specific skills as well as for more generic competencies; (4) they were guided by expert teachers from a training centre outside school. An example is a group of engineering technology students who learn how to analyse and repair problems in a transmission system of a real tractor (provided by a tractor company) with a real problem. During this simulation, students take the professional role of the engineer and repair the tractor, with the help of a teacher. To obtain a variation of hands-on simulations, a set of eight simulations was selected representing different vocational educational levels and domains in the life-

Table 2. Overview of the hands-on simulations included in this study.

Domain	Theme/main tasks	Duration (half days)	Level	Year	*n*	Gender (% male)	Mean age (*SD*)
Engineering technology	Analysing malfunctions in the transmission system of a tractor, adjusting the transmissions system of a tractor, repairing transmission systems of a tractor	10	VET 3	1	8	100%	20.71 (1.70)
Engineering technology	Maintenance of hydraulic systems and troubleshooting of hydraulic systems in tractors	6	VET 3	Mixed	7	100%	22.86 (6.72)
Engineering technology	Diagnosing electronic systems in tractors, diagnosing and adjusting motor systems	8	VET 2	2	4	100%	18.50 (1.29)
Animal husbandry	Organising a concours hippique, managing a horse stable	38	Professional bachelor	1	18	0%	18.79 (1.44)
Pigs, poultry and animal husbandry	Identifying, analysing and guiding breeding processes of various animals (pigs, rodents and reptiles)	8	VET 3	1	18	22.2%	17.16 (0.69)
Retail	Applying various skills of a florist, such as decorating a shop window, wrapping gifts and sales techniques	14	VET 4	1	8	0%	19.29 (8.30)
Retail	Developing a corporate identity, decorating a shop window and furnishing a retail space for a florist	8	Professional bachelor	2	13	7.7%	24.16 (9.60)
Rural environmental development	Conducting applied research on various flora and fauna in nature reserves	9	Professional bachelor	1	51	51%	19.80 (2.42)

sciences. A precondition for selection was that a simulation had to last at least two full days because SRL activities are more likely to occur in longer-lasting simulations. Table 2 gives an overview of the domains, themes/main tasks, duration, educational levels and distribution of students across the eight hands-on simulations.

Participants

Students from various vocational pathways participated in the eight hands-on simulations (Table 2). In the Netherlands, there are two vocational pathways that students can follow after their secondary education: the senior vocational education pathway (VET) or the professionally oriented bachelor's degree. In the context of the European Qualification Framework, the Dutch VET pathway is more practically oriented and equals EQF 1−4+ (Van der Sanden, Smit, and Dashorst 2012). The professional bachelors' degree pathway is more theoretically challenging and equals EQF 6. In the Netherlands, both pathways were reformed according to a competence-oriented qualification structure in 2010. As a result many vocational schools and colleges innovated their curricula according to principles of competence-based education, and an important aspect of competence-based education is to facilitate SRL. With these innovations, it could be expected that the participants (both students and teachers) were exposed to SRL in some form throughout the curriculum. However, this was not identified, nor controlled for, beforehand. Each simulation was instructed and guided by a main expert teacher and was usually supported by other teachers who were experts in the field of the specific subject-matter. The teachers followed courses for coaching and guiding students but were not specifically educated in stimulating SRL.

Data collection

Figure 1 summarises the research process. Non-participant observations were performed by two researchers for two full days per hands-on simulation. The teachers as well as the students did not receive any instruction about SRL and were not informed about the aim of the observations; they were told that the researchers observed the learning situation as it occurred in practice. The observations were conducted using the validated observation

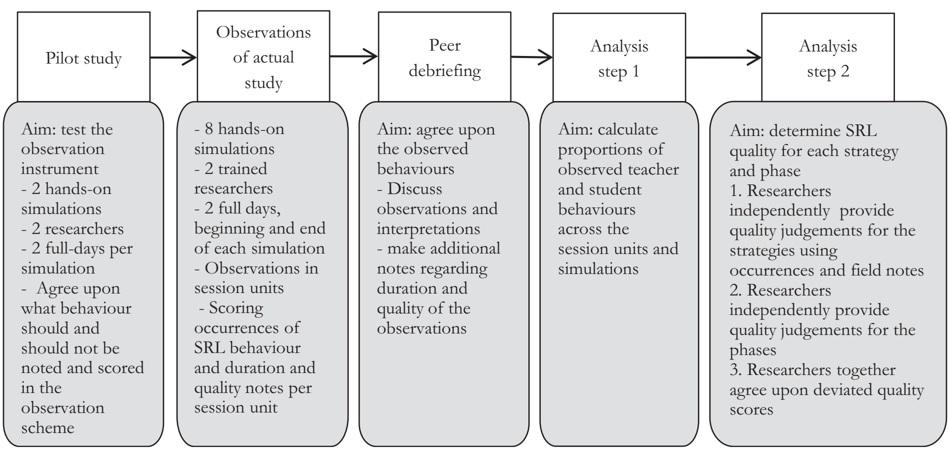

Figure 1. Research process.

schemes for *Powerful Vocational Learning Environments* (De Bruijn and Leeman 2011). The observation schemes consisted of detailed, visible student and teacher activities and behaviour. The student and teacher observation schemes included: (1) powerful SRL strategies; (2) descriptions of concrete behaviour per strategy; (3) room for noting how many times the behaviour occurred; and (4) room for noting down examples of observed behaviour (see Appendix 1).

The observations were conducted on *the first and the last day* of each simulation to ensure that the three phases of self-regulation were covered in the observations. SRL was observed as an *event* (Winne and Perry 2000), meaning that a certain student SRL behaviour and SRL promoting teacher behaviour was ticked off in the observation scheme when it occurred. Also, notes regarding the duration of the behaviours and many examples of behaviours were written down. Observations were conducted in *session units*; when the students transferred to another task, a new observation unit started. Thus, for each simulation, multiple session units were observed during two full days.

During the sessions, one researcher focused her observations on the main teacher; this was a different teacher for each simulation. The other researcher followed a specific group of 3–4 students on whom (s)he focused the observations during all sessions. At the end of each day, the researchers had a peer-debriefing approximately one hour to discuss all observed teacher and student behaviours extensively. During these debriefing moments, the researchers made additional notes regarding duration and quality of observed behaviours across all session units to increase thickness of the data and decrease subjectivity of the observations. Lastly, the data for each hands-on simulation were placed in an Excel sheet, ordered per SRL strategy and session units (see Appendix 1 for an example).

Analysis

Analysis of the data was performed in three steps. The first focused on how much behaviour the teachers and students showed related to the various SRL strategies. Presence or absence of the behaviours was counted across the session units per simulation. Based on these occurrence ratings, proportions of observed teacher behaviour and student behaviour were calculated (% occurrence of the behaviours across session units of each simulation and mean % of occurrences across the eight simulations) and placed in an overview.

Next, a quality score of SRL per *phase* was attributed. To set a baseline, all strategies for each simulation were given a quality score based on the proportions of observed behaviour per strategy (0–25% = –, 25–50% = +/–, 50–75% = +, 75–100% = ++; see Table 3). To achieve a quality rating for the phases, two researchers first independently reviewed teachers' SRL promoting strategies and student SRL strategies, using qualitative field notes and peer-debriefing notes. Then, the researchers independently gave a quality score to the SRL phases. These quality judgements (– low , +/– medium, + high, or ++ very high) were based on observation and debriefing notes about whether the observed behaviour was related to the theoretical framework in combination with observation and debriefing notes about the duration of a specific behaviour:

(1) when the SRL behaviour occurred only very briefly (e.g., evaluation after simulation lasted five minutes) and the behaviour was not good according to the theory (e.g., the teacher only asks the students whether they have learnt

Table 3. Occurrence and quality of the teachers' SRL promoting behaviours and students' SRL behaviour for the various session units in each phase.

		Hands-on simulation								
Phase	Strategy	1	2	3	4	5	6	7	8	Mean % (range)
Fore-thought	*Teacher*									
	Offering choices	60% (3/5)	25% (1/4)	16.7 % (1/6)	50% (1/2)	33.3% (1/3)	75% (3/4)	66.7% (2/3)	25% (1/4)	44% (33.3–75%)
	Modelling	20% (1/5)	100% (4/4)	16.7% (1/6)	100% (2/2)	33.3% (1/3)	50% (2/4)	66.7% (2/3)	75% (3/4)	57.1% (16.7–100%)
	Student									
	Goal-setting	20% (1/5)	0% (0/4)	0% (0/6)	50% (1/2)	66.7% (2/3)	0% (0/4)	0% (0/3)	0% (0/4)	17.1% (0–66.7%)
	Proposing approach/ method for task performance	100% (5/5)	25% (1/4)	66.7% (4/6)	100% (2/2)	33.3% (1/3)	75% (3/4)	66.7% (2/3)	0% (0/4)	58.3% (0–100%)
	Quality	+/–	+/–	+/–	+/–	+	+	+	+/–	
Performance control	*Teacher*									
	Attributional feedback	0% (0/5)	0% (0/4)	16.7% (1/6)	0% (0/2)	0% (0/3)	0% (0/4)	0% (0/3)	25% (1/4)	5.2% (0–25%)
	Verbalisation	0% (0/5)	50% (2/4)	50% (3/6)	50% (1/2)	33.3% (1/3)	75% (3/4)	100% (3/3)	50% (2/4)	51% (0–100%)
	Coaching	40% (2/5)	50% (2/4)	33.3% (2/6)	100% (1/2)	0% (0/3)	25% (1/4)	33.3% (1/3)	25% (1/4)	38.8% (0–100%)
	Scaffolding	20% (1/5)	50% (2/4)	66.7% (4/6)	100% (2/2)	66.7% (2/3)	25% (1/4)	66.7% (2/3)	50% (2/4)	55.6% (20–100%)
	Student									
	Asking for feedback	0% (0/5)	0% (0/4)	0% (0/6)	50% (1/2)	0% (0/3)	50% (2/4)	0% (0/3)	0% (0/4)	12.5% (0–50%)
	Self-verbalisation	0% (0/5)	0% (0/4)	50% (3/6)	0% (0/2)	0% (0/3)	50% (2/4)	0% (0/3)	0% (0/4)	12.5% (0–50%)
	Help seeking	20% (1/5)	25% (1/4)	66.7% (4/6)	100% (2/2)	66.7% (2/3)	100% (4/4)	66.7% (2/3)	100% (4/4)	68.1% (20–100%)
	Quality	–	–	+/–	+/–	–	+/–	+/–	+/–	

Table 3 (*Continued*)

Phase	Strategy	Hands-on simulation 1	2	3	4	5	6	7	8	Mean % (range)
Self-reflection	*Teacher*									
	Progress feedback	20% (1/5)	25% (1/4)	0% (0/6)	50% (1/2)	100% (3/3)	50% (2/4)	0% (0/3)	25% (1/4)	33.8% (0–50%)
	Evaluation	0% (0/5)	0% (0/4)	16.7% (1/6)	50% (1/2)	100% (3/3)	50% (2/4)	33.3% (1/3)	25% (1/4)	34.4% (0–100%)
	Student									
	Self-monitoring	20% (1/5)	0% (0/4)	16.7% (1/6)	0% (0/2)	66.7% (2/3)	25% (1/4)	0% (0/3)	0% (0/4)	16.1% (0–66.7%)
	Self-evaluation	0% (0/5)	25% (1/4)	33.3% (2/6)	50% (1/2)	66.7% (2/3)	75% (3/4)	0% (0/3)	50% (2/4)	37.5% (0–75%)
	Quality	–	–	–	+/–	+	+	–	–	

Note: Proportion of SRL behaviour (%) was calculated using the occurrences of the observed behaviour across the session units for each simulation (between brackets). Quality of the SRL strategies was rated – (low), +/– (medium), + (high) or ++ (very high) for each phase.

something without further interaction with them), a lower quality judgement was given. When the SRL behaviour lasted longer and was of good quality (e.g., evaluations lasted a whole hour and teachers gave each student progress feedback), a higher quality score was given.
(2) when SRL behaviour was short but was of very good quality (e.g., requesting the teachers' help in finding a fault in the motor), high scores were given for help-seeking and when SRL behaviour lasted longer but was of poor quality (e.g., constantly asking the teacher where to find the hammer) lower quality judgement were given for help-seeking.

Lastly, the two researchers met for a face-to-face meeting in which they agreed upon deviated quality judgements regarding the phases.

Reliability and validity

This section describes how the reliability and validity of the data collection and analysis in this study were assured following Poortman and Schildkamp (2012).

Reliability was first assured by using instruments and a data collection method is consistent with the theoretical framework of SRL and the research questions. Second, a systematic approach to data collection was used. All 16 observations were conducted according to the same protocol: (1) all simulations were observed at the beginning and at the end; (2) standardised observation schemes were used in the eight simulations; and (3) at the end of each observation day, observation data were discussed in peer-debriefings to minimise subjective interpretations of the observations. Third, the researchers avoided influencing the behaviour of the observed students by placing themselves in the corner of the room or by standing at a distance from the students. Also, students were informed that the observations could not influence their grading. Lastly, agreement about the quality judgements at the level of the phases was established during face-to-face discussions. Also, the inter-rater agreement (Kappa) of the quality scores regarding the SRL phases was calculated and was .80, which is substantial (Maclean, Wilson, and Gessler 2009).

Construct validity was enhanced by an observation training for the researchers and by collecting thick information. The researchers were trained in using the observation schemes in a pilot with two hands-on simulations for four full days. During this pilot, the researchers constantly discussed what behaviour should and should not be noted in the scheme. Also, observing for two full days made it possible to gather more varied information and to collect data that are rich enough to draw conclusions upon enhanced construct validity. Lastly, the two researchers noted as many example behaviours in each observation as possible to supply a chain of evidence.

Peer-debriefing between the two researchers during data collection and data analysis contributed to the internal validity. To eliminate alternative causal interpretations, the two researchers discussed (for approximately one hour) what their observations were and the interpretations they gave to the observations during the debriefings at the end of each observation day. Internal validity was also enhanced by the use of uniform Excel sheets in which the thick descriptions of all eight simulations were summarised for each simulation separately (see Appendix 1) and after that combined in one overview Excel sheet. These sheets were used as additional material for the individual quality rating and during the face-to-face discussion between the researchers about the quality judgements.

External validity was enhanced by: (1) observing the hands-on simulations that are part of regular educational practice; (2) including simulations across domains in the life-sciences; (3) including students from various vocational educational levels and pathways; (4) directly connecting the observations to the SRL theory; and (5) providing concrete descriptions and examples of teacher and student behaviours.

Results

RQ1: To what extent do teachers show the various SRL promoting behaviours in hands-on simulations?

Table 3 displays what SRL promoting behaviour the teachers showed within the session units of a simulation and across the session units of the eight simulations. The results show that the extent to which teachers promote SRL varied considerably across the simulations, but overall, the teachers used SRL promoting strategies in the forethought, performance control and in the self-reflection phases. On average, in almost half of the simulation sessions, the teachers gave the students moments to choose (44%) and the teachers modelled in more than half (57.1 %) of the sessions. During the sessions in the performance phase, the teachers verbalised (51%), coached (38.8%) and scaffolded (55.6%), while offering very little attributional feedback (5.2%). In approximately one third of the sessions, teachers promoted self-reflection via progress feedback (33.8%) and evaluation (34.4%).

RQ2: To what extent do students show the various SRL behaviours in hands-on simulations?

The extent to which students used SRL strategies varied across the eight simulations (Table 3). Nonetheless, the mean occurrences across the simulations show that there was SRL behaviour in all three phases. In the forethought phase, students proposed a method for task performance (58.3%), while less goal-setting was observed (17.1%). Regarding performance control, the students showed help-seeking behaviours in more than two-thirds (68.1%) of the simulation sessions, but self-verbalised their learning and asked the teacher for feedback in only 12.5 % of the sessions. To conclude, self-reflection behaviour was also observed. In more than one-third of the sessions (37.5%), self-evaluation took place, while in 16.1% of the sessions, self-monitoring was observed.

RQ3: What is the quality of the teachers' SRL promoting strategies and students' SRL strategies, and how do teachers' and students' SRL behaviours look in the three phases with lower, medium and higher quality?

Table 3 shows occurrences and quality of the teachers' SRL promoting behaviours and students' SRL behaviour for the various session units. Table 4 illustrates exemplary behaviour instances of teacher SRL promoting strategies and student SRL strategies in the three phases with lower, medium and higher quality.

Quality of forethought

Five simulations (1, 2, 3, 4 and 8) had a medium score on forethought. In these simulations, there were some moments of choice for students, but most sessions were predefined by the teacher and students did not set goals intentionally. In the three simulations (5, 6 and 7) with high forethought, the SRL promoting strategies that the

Table 4. Examples of teachers' SRL promoting strategies and students' SRL strategies in the three phases with lower, medium and higher quality.

	Forethought	Performance control	Self-reflection
Lower quality of SRL			
Teacher	*Not observed*	• Walks around and watches students working and incidentally coaches or scaffolds students • Gives help on demand	• Asks in a plenary closing conversation with the students whether they want to reflect on their cooperation progress • Closes the simulation sessions without evaluation or reflection
Students	*Not observed*	• Ask for help on call, but questions are of a practical nature (e.g., 'Where can I find the hammer'?)	• Proceed to another session without reflection
Medium quality of SRL			
Teacher	• Predefines the content of all the simulation sessions • Lets students fill in some simulation time on their own	• More prominent place of scaffolding behaviour • Provides students with visual representations of the problem on a worksheet or with a picture • Provides students with extra information for solving the problem viathe Internet • Verbalises problem-solving strategies in interaction with students	• Gives the students a mark for their performance • Elaborates in an individual conversation his/her motivation for grading • Gives progress feedback to individual students (e.g., 'I will not give you a high mark because I had to spoon-feed you throughout the process)'
Students	• Choose their own working groups with respect to size and composition • Allocate tasks based on interests and personal qualities • Do not intentionally set goals for their learning • Continue working on the task without making a plan	• Articulate processes (e.g., 'My challenge was to … And I did …)' • Question their problem-solving strategies regularly (e.g., 'I can drape this (curtain …) towards the back of the window, but then it is not that innovative anymore)' • Ask the teacher for feedback on performance (e.g., 'What do you think of the product I made?' or 'Could you give me a hint so I can improve the product'?)	• Reflect on learning process in an individual closing conversation with the teacher • Explain to the teacher why they thought they deserved a certain mark

Table 4 (*Continued*)

	Forethought	Performance control	Self-reflection
Higher quality of SRL			
Teacher	• Gives considerable freedom to choose what tasks to perform in the sessions • Discusses individual learning goals of students and how they think they are going to achieve these goals during the simulation • Models how to perform technical tasks before the students start to work on their own	*Not observed*	• Gives students progress feedback on their learning process (e.g., 'Very good that you were able to adjust the task during the simulation', 'You did not adhere to the requirements of the task') • Evaluates by giving each student a mark, with comments, for their performance as well as for their learning progress
Students	• Choose the theme of the task according to interests, for example from a folder with all possible options/tasks • Choose how to complete the tasks	*Not observed*	• Articulate their learning progress between the sessions • Give peer feedback for improvement in the form of tips and tricks

teachers used were more on the level of the individual student (e.g., helping individual students to choose challenging themes) and students were more able to plan some sessions according to their personal goals. No simulations scored low, because the students or the teacher showed forethought behaviour in all simulations and the baseline for three out of the four forethought behaviours already exceeded the low rating (proportions were >25%). No simulation scored very high because offering choices and goal-setting was not optimal looking at the theoretical framework in any session of the simulations.

Quality of performance control

The performance control was rated low for three out of eight simulations (1, 2 and 5), because neither teachers nor students used many SRL strategies during task performance and when they did show SRL behaviours, this was mainly occasional, unintentional and did not fit the theoretical framework. The quality of the performance control was medium for five simulations (3, 4, 6, 7 and 8). In these, the teacher coached and scaffolded the students more during task performance and the activities were more in line with the theoretical framework. In one simulation with medium quality, the teacher did not show many SRL stimulating strategies, while the students showed considerably more SRL strategies during task performance that fit the theoretical framework than in low scoring simulations. High or very high performance control was not observed mostly because the SRL behaviours, for the teacher and for the students, seemed incidental instead of intentional and did not relate to the exemplary behaviours of the theoretical framework.

Quality of self-reflection

The quality of self-reflection varied considerably between the eight simulations. In the five simulations with low quality (1, 2, 3, 7 and 8), there were almost no self-reflection strategies from the theoretical framework were observed; sometimes the teacher asked in a plenary session what the students had learnt from the simulations. In the simulation with medium quality (4), there were student SRL strategies in the form of evaluation, but they were highly directed by the teacher. The two simulations with high quality ratings (5 and 6) were characterised by teachers' promoting SRL strategies in combination with students' SRL reflection strategies that appropriately reflect the exemplary behaviours of the theoretical framework. Since the reflective strategies often took place at the end, rather than during the simulation sessions, no simulation scored very high for self-reflection.

Conclusion and discussion

This study identified occurrences and quality of teachers' SRL promoting strategies and students' SRL strategies in the forethought, performance control and self-reflection phases (Zimmerman 2001) in hands-on simulations. The analysis of observation data from eight hands-on simulations revealed that there was considerable variation in the occurrence as well as quality of the teachers' and the students' SRL strategies. In all eight simulations, however, some forethought, performance control and self-reflection strategies occurred. This suggests that today's hands-on simulations are not totally controlled by the teachers but that they, to some extent, stimulate SRL and that students use strategies to regulate their learning in hands-on simulations. However, the picture of SRL in the observed hands-on simulations is by no means perfect. The results clearly show that there is considerable room for improvement with respect to occurrence and quality of teacher SRL promoting strategies and students' use of SRL strategies across the hands-on simulations. Two explanations for these findings are discussed.

First, there were problems with goal-setting in the forethought phase. Teachers generally gave students possibilities to choose, and students felt free to propose methods for their task performance. For students to make proper use of this freedom and goal-setting, they need to adopt task orientation behaviour. Students' task orientation, including orientation on learning needs and goals, is an important step in the process of SRL; students who score high on task orientation tend to use more self-regulatory learning strategies (Suárez et al. 2001). Similar to Jossberger (2011), we observed that this step was skipped; it was common for students to immediately start working on their task, without making an elaborate plan with goals and timing. This might be explained by the fact that students in our study were in their first or second year of vocational education. Novice vocational students are used to teacher-provided structure of learning and are not naturally capable of using SRL strategies, with the consequence that they are not capable of selecting the right tasks on their own (Kicken et al. 2009). SRL skills, such as goal-setting and planning, are developed gradually scaffolded by teachers (Taks 2003). This gradual development is complicated by the fact that hands-on simulations are often treated as an isolated learning activity instead of an integrative part of the vocational curriculum (Khaled et al. 2014). The hand-on simulations in this study are even outsourced to a professional, but external, training centre. To gradually help developing goal-setting skills, intertwining learning in school and learning in hands-on simulations is required. Hands-on simulations should offer opportunities to work on goals, or personal gaps, identified in school and vice versa. For example, teachers can introduce self-assessment via e-learning tools prior to the simulation. Because students' self-assessment is most accurate when they are presented with standards (Andrade and Du 2007; Kicken et al. 2009; Stefani 1994), simulation teachers can, for example, provide students with video-recorded examples of good performance tasks (including process steps) via the e-learning tool that students can use to self-assess and set goals before going into the actual hand-on simulation.

A second explanation for the findings can be that fostering SRL is often not the primary focus of many teachers in vocational education, including teachers in schools that claim to have innovative curricula, and which among other outcomes, aim at increasing students' self-regulatory behaviour to some extent (Sturing et al. 2011). In a previous study, vocational teachers were asked to rank the importance of 10 principles for competence-based education one of which was stimulating self-regulation (Sturing et al. 2011). The results showed that SRL was ranked only in seventh place. Since teachers are proven activators of effective SRL (Hattie 2009), it is no surprise that SRL is still underexposed and underdeveloped in vocational students and in specific learning environments in vocational education, like hands-on simulations. Thereby, the life-science teachers (mostly men) in our study have a passion for their domain but tend to have less affection for educational innovations. Problems with confidence and commitment to SRL often have to do with the teachers' misconception that SRL equals minimal guidance (Van Hout-Wolters, Simons, and Volet 2000). Therefore, there is much to gain by increasing teachers' awareness of the importance of SRL for the development of competencies, also in hands-on simulations.

In addition, it was striking that there was very little proper self-reflection observed across the simulations while a recent literature review showed that stimulating self-reflection is precisely one of the strong learning environment characteristics of hands-on simulations (Khaled et al. 2014). Hands-on simulations offer ample opportunities for reflection-in-action by pausing simulations to reflect, as well as for reflection-on-action by reflecting on, for example, videotaped behaviours. In our study, teachers did not adopt these reflection stimulating activities, and students perhaps in response to that did not employ reflection behaviour. Occasionally, the teachers reflected with the students at the end of the simulation. However, self-monitoring was rarely observed, although it is an essential aspect of self-reflection (Winne and Hadwin 1998). Self-monitoring provides awareness of one's performance, which can be used for further steps towards learning goals (Zimmerman 2001). Simulations lasting longer than one session or that students have to participate in multiple times during their educational pathway (which is often the case in life-science education) provide many opportunities for self-monitoring. Teachers can, for example, structurally use the time between simulation sessions to guide students with monitoring their competence and help them determine what they need in subsequent sessions to fulfil their learning needs.

Besides, there was no systematic relationship found between SRL and other factors that explain the results. It was difficult to pinpoint other factors that possibly influenced SRL. For example, we could not confirm the assumption that the use of self-regulated strategies is related to cognitive abilities and information processing capabilities (e.g., De Bruijn and Leeman 2011). Because there were no structural differences in results between the simulations at the VET and the professional bachelor's degree level. Also, there were no structural differences between the simulations in which the majority of the students was female compared to the simulations in which the majority was male. Thus, gender-bound differences in SRL, such as the preference for female students to use self-regulatory learning strategies compared to boys (e.g., Herrington and Herrington 2006; Barab, Squire, and Dueber 2000), also did not hold for our study.

Limitations

In this study, students and teachers were observed by two researchers during their participation in a hands-on simulation. The advantage of this method, compared to asking teachers and students in retrospect, is that this exposed what teachers and students actually did to regulate learning instead of assuming that what they say they did actually happened. This method also has some limitations: for example, SRL is a process that is not completely observable (Maclean, Wilson, and Gessler 2009). Outsiders, such as researchers, cannot see what teachers and students think. Therefore, we might have missed strategies related to SRL that were not verbalised or expressed in observable behaviour. Second, although we observed each simulation for two full days at the beginning and the end, we were not involved as observers in the simulation sessions in-between these days. It is possible that SRL strategies, other than those reported in this study, were used in the simulations when the observers were absent. Third, this study was conducted in hands-on simulations in domains within the life-sciences at a simulation training centre outside the school setting; further research on SRL strategies in other educational domains might lead to different outcomes, as the structure of hands-on simulations might slightly differ between domains, and simulations in training centres might have different structures than simulations inside vocational school settings.

In sum, even though our hands-on simulations were all part of an innovative vocational curriculum that aimed at implementing competence-based education in which stimulating SRL is seen as an important process towards competence development, stimulating SRL did not reach as far as hands-on simulations. Specifically, the goal-setting and self-monitoring of the students, and teachers' belief in SRL and the ways in which they more explicitly create opportunities for adopting SRL behaviour (see also Jossberger 2011) need improvement. Nevertheless, the findings of our research open doors to SRL in simulations. We found that hands-on simulations were not totally controlled by the teachers and that students had possibilities to self-regulate their learning. Future research should first focus on improving SRL in hands-on simulations if (and only if) fostering learning outcomes such as competencies is the goal of the hands-on simulations. After that, educationalists can examine how hands-on simulations with low, medium and high SRL affect the intended learning outcomes in vocational education, such as competencies, and precisely how the various SRL strategies contribute to these outcomes through hands-on simulations.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Examples of students and teacher observations based on De Bruijn et al. (2005) and De Bruijn and Leeman (2011).

		First day				Last day			
		Session unit 1		Session unit 2		Session unit 1		Session unit 2	
Strategy	Concrete behaviour	Occurrence	Examples	Occurrence	Examples	Occurrence	Examples	Occurrence	Examples
Teacher									
Offering choices	(1) The teacher lets the students decide on how they are going to complete the task	1	The teacher lets the students choose how they want to present their results (for example, via PowerPoint, via a collage or with photo's)	1	The teacher lets the students choose the theme of the mood board.			2	The teacher tells the students that they may choose how to design the store
	(2) The teacher lets the students decide on what tasks they are going to choose	1	The teacher tells the students they can choose what they want to do during the coming sessions (e.g., work on the corporate design of the shop, work on the Internet site of the shop)						