Integration of academic and vocational disciplines in simulated practice

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As we walk up to the spot we are planning to film the interview, Hafid tells me he is working nearby at a supermarket. He stopped for a while with school, earning some money, meanwhile re-applying for a metal workers training. The Dutch language was the problem at the school where I met him during my research. It was not just the Dutch, I remember. There were also the problems of him taking care of his family, since he was the eldest in the household and able to understand Dutch.

The Dutch teacher, didn't she help you with your presentation in the end?
Yes.
But she could not help you overcome you troubles with the language?
Yeah, a little. It is just hard.
And now you still want to become a metal worker, how are you going to manage the Dutch at that training?
I am practicing. And have to take a test first. There not so much Dutch then.
You like to work with metal?
Yes, I really want to do that. Mr. John has learned me that.

Once the camera is set up, and Hafid and I are ready, we start the interview. Hafid is relax, as he always was during the project at his school. He is very willing to answer all my questions, some of which I already asked him before.

Something I still remember about the tricycle, is that you first had a one drawing and suddenly later the drawing was totally different.
Yeah, that first drawing, I drew wrong, not drew wrong, but planned wrong. Later I had a little help from Mr. John, got a little help from him, then I had thinked it out, so to speak.
Tought.
Yeah, thought out, welded, everything.

Abstract

In vocational education students are to be prepared to participate in communities of practice (Maes, 2004). Hence they need technical skills as well as content knowledge e.g. science and mathematics. Research has shown that the instructional strategy of guided co-construction may lead to deeper understandings within a practice (Van Schaik, Van Oers & Terwel, 2010/2011; Snel, Terwel, Aarnoutse & Van Leeuwen, 2012). Guiding in a co-constructive way means helping students to collaboratively reconstruct models and subject matter knowledge through an on-going and reciprocal discursive process, focused on the solution of task-related problems (Mercer, 1995; Hardman, 2008). This paper focusses on students' drawings and models and their function in a 'web of reasons' (Brandom, 1994). The present research takes a cultural historical activity theory perspective on how students (age 14-16) and their vocational and subject matter teachers use models and other representations as tools in the process of designing and constructing (Van Oers, 2006; Billet, 2003). We use video data from a design based research project at schools for preparatory senior secondary education, for which students had to design and built a prototype of a tandem tricycle. Teachers guided the students in this process aiming at not only acquiring technical skills, but also at an understanding of codified knowledge (Van Schaik, et all, 2010/2011).

The present research explores how the models functioned for the students in the simulated workplaces at school as reasons for action and how these reasons evolve over time and through guidance of the teacher. From a body of about 10 hours of video data we selected 18 interactions of students and teachers on or over their models and drawings from early in their design and construction process till the end. By identifying the change of meaning and the role the representations play in students' web of reasons, we can explain students' (differences in) understanding of models and concepts of mathematics and science. The results showed that students' actions, tool use and products concepts and knowledge play an important roll as object-motives (Edwards, 2010).

We propose that emphasis should be on the inferential role of concepts and representations in order for the students to be meaningful and to be used as tools in a practical way (Bakker & Derry, 2011). This proposition may help to bridge the gap that exists for students and teachers in vocational education between practical, explicit, situated knowledge and codified, general knowledge. Hence integrating the vocational and academic disciplines. Moreover, a web of reasons can be a pedagogical tool for teachers within a strategy of guided co-construction.

Keywords: modeling, co-construction, models, vocational education, web of reasons

Introduction

In this paper we report on a design study in pre-vocational education (VMBO)[1], which explored the process of an intervention aimed at enhancing students' codified knowledge in mathematics and science, as well as their understanding of modeling, while in the process of designing and constructing a tricycle.
In many educational settings knowledge is codified in subject matter textbooks

and other curriculum tools, most of it derived from academic disciplines (Eraut, 2004). In vocational education, as well as in workplaces, codified knowledge is also available in bodies of rules (Guile & Young, 2003) and other specific tools, including, for example, machine manuals. Students in vocational education have to acquire this knowledge and at the same time become skilled in relation to their future professional practice. They are thus required to obtain competencies in order to be prepared for future demands, including codified knowledge as well as technical skills and attitudes (Cedefop, 2009; Commission of the European communities, 2008). However, relatively little research has been carried out into the type of learning environment in vocational education that is supposed to promote this kind of learning (Koopman, Teune, & Beijaard, in press).

The abbreviation VMBO denotes the system of preparatory vocational education at the secondary level in the Netherlands (Eurydice, 2008; Maes, 2004). Students between 12 and 16 years old follow a general curriculum with a vocational perspective. Work experience for students is organized both in school workplaces and extramural apprenticeships. The students' work experiences are used for developing generic skills and knowledge, as described in the generic model of work experience of Guile and Griffiths (2001). However, general subject matter is often separated from practical vocational skill teaching. In our research project we examine the quality of the learning outcomes in educational situations in which subject matter theory and vocational skills are integrated, following a design-based research approach (Barab & Squire, 2004; Collins, Joseph, & Bielaczyc, 2004; Shavelson, Phillips, Towne, & Feuer, 2003; The design based research collective, 2003). Earlier studies showed that students can, given practical problems in the vocational workshops[2], be guided towards a theoretical understanding of codified knowledge (Van Schaik, Van Oers & Terwel, 2010a; 2011). The studies in question demonstrated that a design and construction assignment might be potentially knowledge-rich. We learned from follow-up studies that explicit attention to models as tools resulted in a better understanding of models (Van Schaik, Van Oers & Terwel, 2010b).

For the present paper, we selected two of the four schools of an intervention study in which there was a special focus on more explicit connections between product design and appropriation of subject matter knowledge. Students were asked to design and build a prototype tandem tricycle. Teachers subsequently assisted the students in dealing with problems during the tricycle design and production stages. The students were encouraged to use or develop models to solve the problems they encountered in working on this 'real-life' assignment. As we learned from the previous studies, stimulation in the practice workshop is insufficient for the reconstruction of subject matter knowledge and models on the basis of practical problems alone. In that light, we created a series of 'prototype lessons', during which students were guided to move from practical solutions and drawings to codified subject matter knowledge and models.

Theory and practice in pre-vocational education

By way of an attempt to improve the relevance of knowledge and the effectiveness of knowledge transfer to the workplace, as is the case in other countries a reform is taking place in Dutch pre-vocational schools (Guile & Young, 2003; Seezink & Van der Sanden, 2005). One of the proposed reforms envisions the teaching-learning process as an activity embodied in a simulation of real world practices. Students work on products for 'real' customers and in this context they are guided by teachers to acquire knowledge and skills. The basic assumption behind this approach is that learning of codified knowledge and vocational skills can be integrated into authentic workshop practices. The pedagogical approach can be characterized as what Tynjälä (2008, p. 144) calls “integrative pedagogics”. However, working on a (practical) problem is not enough to motivate students to learn (Guile & Young, 2003), and participating in real life situations is insufficient to develop higher level expertise (Tynjälä, 2008, see also Schaap, Baartman & de Bruijn, 2011). The challenge for schools is to design assignments that are meaningful for the students and relevant to their future jobs (Tuomi-Gröhm & Engeström, 2003; Volman, 2006). At the same time, assignments should also result in highly qualified learning outcomes that enable students to recontextualise their knowledge and skills from the classroom to the workplace. In short, teaching should support students in relating practical problem solving to codified curriculum knowledge (Guile & Young, 2003; Van der Sanden, Terwel, & Vosniadou, 2000). From this perspective therefore, students need to be supported when solving real life problems with “conceptual and pedagogical tools which makes it possible for them to integrate theoretical knowledge with their practical experiences.” (Tynjälä, 2008, p.145).

In our previous studies we investigated this process in detail (Van Schaik, Van Oers & Terwel, 2010a/b), exploring the implementation of two assignments and the subsequent teacher guidance at one school and testing whether or not the learning environments had become *knowledge-rich* (Guile & Young, 2003). It turned out that designing a tandem tricycle can, in fact, create opportunities in teaching students codified knowledge and modeling. The present study builds on those findings.

The research questions in this paper aim at finding out how the pedagogical strategy of guided co-construction is effective in joining experience and general knowledge. The analyses focus on students’ drawings and models and their function in a ‘web of reasons’ (Brandom, 1994).

Models as tools

In pre-vocational education students both design and construct real products. During the design and construction processes problems arise that need to be solved. Models may be used to anticipate possible problems and their solutions. Although drawings and models are important in design technology and serve to communicate and generate ideas, MacDonald & Gustafson (2004) claim that classroom emphasis is merely on their representational function. Students must be able to draw correctly, while their models, including assessment, are used for teacher diagnostics only. If students’ classroom drawings were preceded by students' orientation towards the problem situation and the exploration of ideas, modeling might develop into an active learning strategy which could help students gain deeper understanding of problems and their possible solutions. This assumption is in line with the view of Tuomi-Gröhn and Engeström (2003). Rather than primarily having a diagnostic and explanatory function, models serve a dual purpose:

> “On the one hand, the practitioners model the past and present contradictions in their activity system in order to understand where the causes of trouble lie and on which aspects of the activities they shall focus

> their change efforts. On the other hand, the practitioners model also a future vision of their activity, in which they depict expansive solutions to the contradiction.” (Tuomi-Gröhn & Engeström, 2003, p. 32).

In this article models are defined, following Van Oers’s (1988), “... as any material, materialized (for example a graphical display) or mentally pictured construction, built up from identifiable elements and relations, which structures the user's action ...” (p.127). These models function as tools in orientation and communication activities, in ways similar to those described by Tuomi-Gröhn and Engeström. For example, a model may allow the designer to calculate angles in a drawing in advance, so that steel may be sawn correctly in one single process, rather than by trial and error. Here the mathematical formula functions as an orientation tool. When, with regard to the present context, the drawing is used by students to negotiate the design of the tricycle with others, it also becomes a tool for communication. Hence, orientation and communication are both functions of a model, which can consequently serve both at the same time.

Formation of a web of reasons

Using models as tools in the vocational education practice workshops can serve both students' technical codified knowledge and the more general knowledge in subjects such as mathematics and science. When models as well as the accompanying planning solutions are used as means for orientation and communication in relation to present and future problems students' *disciplined perception* may develop (Stevens and Hall, 1998). This implies that students become familiar with the modes of thought that prevail in the discipline. In pre-vocational education the disciplines comprise both general curriculum subjects (derived from academic disciplines such as mathematics and science) and vocational disciplines, in our case those in the technical and technological domains. Students should be supported to “... gain a greater awareness and appreciation of the discourse repertoire … and how it is used to create knowledge and to get things done” (Mercer, 2002, p. 147). They are therefore required to actively construct knowledge and information, applying the system of artifacts used in the practice of the discipline (cf. Beach, 2007). However, according to Stevens and Hall, “disciplined” also implies that “learning to participate in disciplinary practices does not depend solely on 'instruction and exercise'...”(p.109). Therefore, a simulation of a actual vocational practice may help students to become 'disciplined'. That is, students become trained in the discipline(s) and can participate using the language and tools of the discipline(s).

Subsequently, students' reasoning evolves in a similar way: “they learn to make connections between the different concepts and techniques, so as to form an integrated whole” (Bakker & Akkerman, submitted, p.x). In other words, that they become aware of the web of reasons of the discipline(s). This web refers “to the complex of interconnected reasons, premises and implications, causes and effects, motives for action and activity, and utility of tools for particular purposes that are at stake in particular situations” (ibid). In our previous studies we have found that often students actions are determined by mostly practical reasons, for example the dimensions of the tricycle by availability of specific parts of steel instead of the length of the users. Also their original plans as represented in their drawings fade into the background. We also found that the drawings could be used to direct the students to the disciplinary knowledge in the drawings and models. Hence, when the teachers use the students' plans, drawings and models and the knowledge involved in their guidance, the students can be supported, in a integrative way, to develop a disciplined perception. Meanwhile the students reasons for action may become more theory laden.

Guided co-construction

In the above light, using models should become a strategy to solve problems, with teachers assisting students in their attempts to understand the potential problem solving function of models; in other words, assisting students in understanding the orientation and communication function of models, as opposed to their mere representational function. Drawings and models should not only be viewed as subtasks without any relation to the final goal of designing.

By collaboratively reflecting on and improving the production process, participants learn to understand the often tacit rules and codes of the workplace and the knowledge underlying them (see also Lave & Wenger, 2005). As tools for communication and orientation models may assist students in thinking ahead and reflecting on their own process and product. Students' understanding may increase as a result. On this view the teacher's role is to support reflection on the models and thus to discursively guide the students in their process of (re)constructing the appropriate models that optimally serve both functions for the task in hand. Guiding in a co-constructive way thus means helping students to collaboratively reconstruct models and subject matter knowledge through an on-going and reciprocal discursive process, focused on the solution of task-related problems. It is the teacher's role to " … maintain connections between the curriculum-based goals of activity and a learner's existing knowledge, capabilities and motivations" (Mercer, 2002, p. 143). Research has shown that the instructional strategy of guided co-construction may lead to a better understanding of mathematics and modeling than a strategy based on models that only provide (Doorman, 2005; Terwel, Van Oers, Van Dijk, & Van Eeden, 2009; Van Dijk, Van Oers, & Terwel, 2003). Mercer (2002) summarizes the characteristics of teachers who were successful in supporting pupils in their development of mathematical problem solving and reading comprehension. Above all, such teachers use questions "not just to test knowledge, but also to guide the development" (Mercer, 2002, p.144). Secondly, the teachers taught more than subject content. They also assisted students in understanding the problem-solving strategies and making sense of their experiences. Finally, "they treated learning as a social, communicative process" (ibid.). All of these characteristics are elements of what we call guided co-construction.

In one of our previous studies, which comprised interventions at two schools, a program based on the tricycle assignment was designed and teachers were trained to guide the students either in a co-constructive way or in a providing way (Van Schaik, Van Oers & Terwel, 2010b). It turned out that the students in the co-construction conditions produced better product models.

To summarize: when students are guided in a co-constructive way during a design and production process, their understanding of the disciplines may be supported if the models are used as tools in a web of reasons. Therefore our research question is: *how do models function for students in simulated workplaces at school as reasons for action and how do these reasons evolve over time and through guidance of the teacher?*

Method

The present research takes a cultural historical activity theory perspective on how 8 students (age 14-16) and their vocational and subject matter teachers (n=2) use models and other representations as tools in the process of designing and constructing (Van Oers, 2006; Billet, 2003). We use video data from a design based research project in which, during an intervention at schools for preparatory senior secondary education, students had to design and built a prototype of a tandem tricycle. Teachers guided the students in this process aiming at not only acquiring technical skills, but also at an understanding of codified knowledge (Van Schaik, et all, 2010a/b/2011).

This paper explores how the models functioned for the students in the simulated workplaces at school as reasons for action and how these reasons evolve over time and through guidance of the teacher. From a body of about 10 hours of video data we selected 18 interactions of students and teachers over their models and drawings from early in their design and construction process till the end.

The methodological approach can be characterized as a 'whole to part' approach meaning that analyses started with reviewing and labelling video at school level, after which a microanalyses of student-teacher and student-student interactions was performed at classroom level (Erickson, 2006).

Intervention

The intervention design was primarily based on experiences from the preceding studies (Van Schaik, Van Oers & Terwel, 2010a/b; 2011), which revealed that designing and building a tandem tricycle may evoke the use of models and technical knowledge, and that guided co-construction in this process improves the quality of student models. The four schools involved were allowed to effect local adjustments in order to maintain their school culture, thus keeping the ecology as authentic as possible. We agree with Lemke and Sabelli when they point out on the basis of complex systems theory that “Adaptation of models for system reform to local conditions matters more than efforts to replicate success elsewhere” (2008, p. 125). Although our intervention is not a system reform, we acknowledge that the design used in previous studies needs to be adaptive to the local conditions of the schools in this study. In effecting local adjustments the agency of the participants was respected and, as a result, the program changed when used as a tool by the participants. An appropriate way to characterize our method would be to place it in the tradition of formative intervention (Engeström 2007; 2009). The complexities involved in studying different school practices were also acknowledged (Goodlad, Klein, & Tye, 1979). We therefore follow Downing-Wilson, Lecusay & Cole (in press) in that, on the basis of joint activity with the teachers, the intervention was interpreted and changed by all parties involved. Since we analyzed the “design as implemented” (Ruthven, Laborde, Leach, & Tiberghien, 2009, p. 341) and adopted the “enactment perspective” to examine the implementation (Snyder, Bolin, & Zumwalt, 1992, p. 418), the intervention itself evolved as a result of our research interactions (see 'implementation').

The intervention consisted of a student assignment (see below) plus an educational instrument for the teachers. It consisted of a series of embedded *prototype lessons* and *examples of problems* that students might encounter in design and construction processes. The teachers were supposed to pay explicit attention to the way students' situated knowledge was related to more general knowledge; moving from practical problems to modeling by the use of mathematical and scientific concepts. The prototype lessons were the instructional moments for reflection on the practical problems and their underlying principles.

Participants and setting

The intervention was implemented at four schools for preparatory senior secondary education (VMBO). VMBO educate students with a dual perspective: general-theoretical and vocational (Cedefop, 2009; Maes, 2004). Students are between 12 and 16 years old and are prepared for secondary vocational education in both general subjects as mathematics and languages as well as vocational disciplines such as mechanical engineering. The two schools in this study were selected out of the four from the total intervention, because they were the better performing ones, as found in previous analyses (Van Schaik, Terwel & Van Oers, in press).

School 1: Orthen Technical School This school had 15 students working in five groups of three. The workshop space was large and had recently been refurbished. Computers and a separate instruction space were available. Students were guided by two practice teachers and one teacher who taught the prototype lessons and normally functioned as a welding teacher but who used to be a mathematics and physics teacher. Computers with 2D-CAD software were used for the drawings. Prototype lessons (three out of five) were taught separately to the whole group. This school scored above the sample mean on two of the three pre-measures.

School 2: Technical College Oldenhave At Technical college Oldenhave four groups of four students out of a class of 24 chose to work on the assignment (two other groups worked on other authentic assignments). Students worked in two spaces: one, their 'own', with computers and some technical equipment, and one reserved for metal working (i.e. grinding, sawing metal and welding). A team of four teachers guided the students; both subject matter and practice teachers. Students used subject matter classes for their ' theoretical' problems. The content of the prototype lessons was taught in situ. Students used computers with 2D and 3D Computer Aided Design (CAD) software for their drawings. The project ended with a presentation to their peers. The mean scores of the students on all pre-measures were higher than those for the other schools.

At both of the schools one subgroup of four students was selected for the present analyses. The groups were the winners of the competition at their schools.

Student assignment

The students' assignment was the following:
Design and build a prototype of a tandem tricycle for children aged 4-7 in such a way that the children have to cooperate.
The assignment was placed in the context of a competition.

The students were asked to design and build the tandem tricycle in ten weeks. During that period they worked at least two hours a day in the workshop setting and in open classrooms, where computers were available. Teachers were available for questions and guidance in both spaces. The design process was reflected on during workshop hours and in lessons or sessions separate from the workshop and the construction process (the prototype lessons). During workshop practice mainly practical problems encountered were most of the time solved directly or redirected to separate lessons, in which teachers guided the students in problem solving by using their designs as well as relevant science and mathematics subject matter.
For the students the process s started with an introduction by the researchers, who explained the purpose of the assignment, which was to build a prototype to win a competition. The students started designing during the first week (see figure 1 for an example) after which they moved on to construction in the weeks following. The competition ended initially with the selection of the two best prototypes at every school, which was followed by a final session during which a jury decided which prototype was the best (figure 2).

Figure 1: Students' design at school 1 condition (video still)

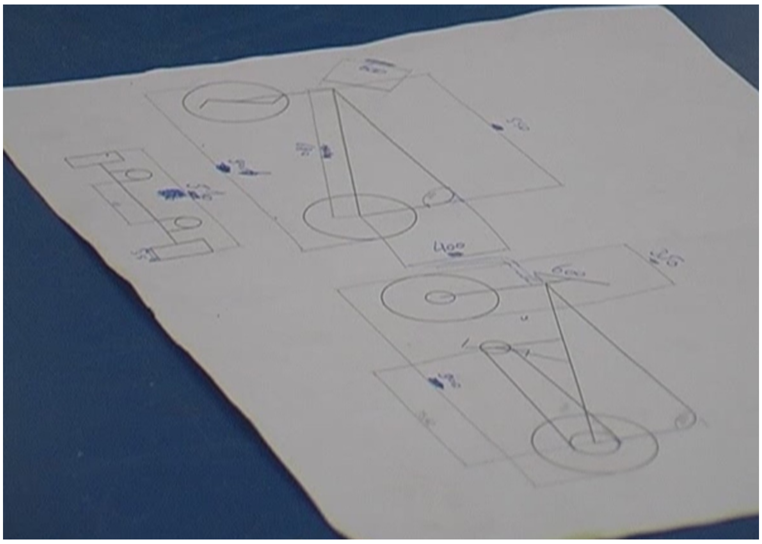

Figure 2: The winner tricycle of the competition chosen by the jury of experts.

Teachers' educational instrument

A teacher instrument was developed which consisted of a series of embedded *prototype lessons* and *examples of problems* that students might encounter during the design and construction processes. The instrument differed according to the way the students in the two conditions had to be guided. For the experimental condition the instrument consisted of a 'toolkit' with possible content for prototype lessons and templates for ad hoc lessons and instruction. The toolkit was intended as a reference base for the teachers. For the control condition the instrument consisted in a detailed lesson plan for the teachers to follow.

Implementation

Looking at the logs that were kept by the researchers during the school implementation part of the project, we found that schools differed in how well they followed the teachers' educational instrument; that is, how the intervention was carried out compared to how it was originally designed. In addition, from the interviews with the students and teachers we learned the extent to which the project differed from the way assignments were normally carried out. At School 1 in this study the main difference lay in the fact that students normally work alone. For the tricycle assignment students could make their own decisions on how to proceed with the design, whereas they would normally follow a fixed procedure for other assignments. In the words of one student: "You couldn't do anything wrong … you simply could choose whatever you wanted [on how to construct]." At School 1 students were used to having a drawing provided and constructed only smaller components, instead of something that, in the words of one student, "will really be used." The only difference with regular practice at School 2 was that this time the assignment was not for a 'real' client, but for a competition. In their regular practice students also have a client, an assignment and a budget, and proceed from there in their subgroups.

From interviews it also became clear that at a subject-matter teacher was involved when students worked in the workshop. Of the teachers at School 2 who guided the students, two also taught mathematics or physics, although not to students in the project. At school 1 the teacher who taught the prototype lessons had formerly been a mathematics and physics teacher and normally taught welding.

Video procedure

The reason to use a video approach is that we wanted to analyze both the micro-genetic learning trajectory of the students and the development of the intervention (cf. Mercer, 2008). Using video, next to other forms of data, it was possible to identify "the changing participation of the students in group interaction" (Erickson, 2006, p. 181).

Collecting the observation data, we looked for interactions on how students used knowledge and mathematical models and how the teachers helped them to use those, when solving the problems they encountered. We had three cameras in the classroom: two overall cameras and one hand-held camera. The two fixed cameras were continuously recording and one of the fixed cameras also recorded the audio that was captured by means of a wireless microphone attached to the teacher. The third hand held camera was operated by one of the researchers (always the same person) and captured those interactions in which students and teachers together, or students by themselves were solving problem (for a more detailed description see van Schaik et al., 2010a; Van Schaik, 2009). In addition, we video recorded the interviews with students and teachers we held shortly after each observation.

The selection of the video sections for analyses was based on the assumption that manifestation of the students' reasons for action could be found in interaction with each other or with the teacher. The additional criterium was the presence of drawings or models.

Video analyses

Video analyses were conducted using TAMSS analyzer (Weinstein, 2006). First interactions over drawings and models were labelled, next those the utterances in those interactions were coded using Bakker and Akkerman's operationalization of the level of integration of types of knowledge (Bakker & Akkerman, submitted). Table 1 shows the four levels. 'Statistical-mathematical' in the original is replaced with scientific-mathematical/vocational as the two kinds of disciplines established in the theoretical framework above.

Table 1

Levels of knowledge integration used as codes in the data analysis (derived from Bakker & Akkerman, submitted)

Level	Characterization
1	Statement about something scientific-mathematical/vocational *or* work-related but without explanation or reasoning
2	Reasoning or explanation with only scientific-mathematical/vocational *or* only work-related (non-theoretical) knowledge.
3	Statement in which a scientific-mathematical/vocational fact *and* a work-related fact are combined.
4	Reasoning with both scientific-mathematical/vocational *and* work-related knowledge

Results

At every school we observed four lessons, all practice lessons. At school 1 we also observed a prototype lesson. At school 2 there were no separate prototype lessons; the subject-matter teachers at that school were present during the regular practice periods and the content of the prototype lessons was taught in the context of those practice lessons. All together we gathered almost 12 hours of video data (see table 2).

Table 2
Video data and number of representations

	School 1 Lesson type	School 1 duration of video obs.	School 1 number of repr.	School 2 Lesson type	School 2 duration of video obs.	School 2 number of repr.
Week 1						
Week 2						
Week 3				Practice	1:09:09	4
Week 4	Practice (drawing)	1:08:13	6			
Week 5						
Week 6	Practice	1:46:46	7	Practice	1:53:05	3
Week 7	Practice	0:57:07	5			
	P-lesson	0:31:21	1			
Week 8						
Week 9						
Week 10	Practice	2:13:39	0	Practice	1:25:48	3
Week 11				Interview		
Later				Presentations (3)	0:52:05	3
Total		6:37:06	19		5:20:07	13

When we look at the number of presentations (drawings and models) during the observations we can see that school 1 had six more in total. However at school 2 representations were still present at the end of the process, whereas at school 1 as the process evolved the representations disappeared. This is in line with our previous findings (Van Schaik et al., in press).

18 episodes were selected in which the students we followed for this study were present. Most of those were around the episodes in which representations were visible. In two episodes there were no representations.

In all episodes and in an interviews we code the utterances to the level of integration (table 3). As with the representations, at school 1the prevalence of utterances with some level of knowledge decreased towards the end of the process. At school 2 however, in the final presentations students still showed integration of knowledge. Another difference between the schools is the level of integration. At school 1 only level 1 and level 2 utterances were found, whereas at school 2 also level 3 integration was coded. No level 4 was found in the observations.

Table 3
Level of integration in utterances

Levels of integration	School 1 week 4	School 1 week 6	School 1 week 7	School 1 week 10	School 2 week 3	School 2 week 6	School 2 week 10	School 2 Week 10 (interview)	School 2 Presen-tation
Level 1	8	8	4	4		4		1	2
Level 2	1		1			3			1
Level 3						4		2	2
Level 4									

Analyses of student use of representations and reasoning

The analyses of the prevalence of the utterances over the process shows that it resembles the appearance of representations. As found in earlier studies, representations, as tools during the design and production process, tend to dissapear towards the end of the process. This seems also the case for utterances that have a level of knowledge in them. Only at school 2 both drawings and utterances with knowledge remain present in the end of the process. The turning point in this study seems to be week 6. The majority of the representaions as well as the utterances at all levels decreases from there.

At school 2 more level 2 utterances are found and only at that school statements that contain both practical and subject-matter/vocational knowledge arre found. This may be due to the fact that students at that school had to present there final prototype, including the drawing and reflection on the process, to their peers. In this presentation students still made statements at level 3. In the next paragraph examples of the utterances are shown.

Examples of level 1 statements

Most utterances found in the observations are at level one. The statement vary from very short ones about tasks, dimensions, materials, or measures as example 1 shows, to statements on what students do and have done in example 2.

Three of the four students of the subgroup are together and looking at their design. One of them is playing with measurement tape.

Example 1
School 1 week 4

	Utterance	Remarks
Student	These are far to small dimensions.	While looking at the measurement tape

In the final presentation for peers at school 2 the subgroup presents the prototype and reflects on their process. One of them explaines why their design drawing is not finished. That is, the drawing does not accurately reflects the actual product they constructed. There is not much more than that.

Example 2
School 2 peer-presentation session

	Utterance	Remarks
Student	So, this is the design drawing as actually built, but it is not finished yet.	Peers are laughing and comparing the drawing with a map.

Examples of level 2 explanations/reasoning

There were three instances of level 2 reasoning. The examples here are typical for the explanations at both schools when students are asked to explain the reasons for their design an prototype. It shows that most reasons are practical or at least are not connected to knowledge.

Example 3
school 2 week 6

	Utterance	Remarks
Student	When you that that, then the chair also has to come further like this. Otherwise we can not attach it.	Moving around with parts of a chair for the tricycle on the workbench.

Example 4
school 1 week 4

	Utterance	Remarks
Student	Sir, we were thinking that, if the wheels are right here, then there is 'lost space'. So we were thinking to put here another chair and then on the other side as well. That way two guys could sit on it.	Referring and pointing to a drawing on the computer screen in AutoCad.

Examples of level 3 statements

Only at school 2 level 3 statements were found. Most (4) were in week 6, in the final presentation, there were 2. In week 6 the subgroup is discussing their plans for the construction. The talk what can be done, by whom. One of the students states something about the rear of their design by which he uses mathematical issues in the design that first have to be solved before the practical tasks at hand can be carried out.

Example 5
school 2 week 6

	Utterance	Remarks
Student	At the rear we need a triangle. I still have to decide on the degrees to see how big the triangle will be.	While the subgroup is sitting around the computer with the printed drawing in front of them.

In the same presentation as in example 4, an other student of the subgroup explicitly refers to their drawing as a tool. With this statement he shows that he knows what the rules for a technical design drawing are, but that theirs does not comply to those. In other words, he shows an understanding of vocational knowledge.

Example 6
School 2 peer-presentation session

	Utterance	Remarks
Student	Coming back to our drawing, we were mainly busy with our product, so the drawing has suffered as a result. So it isn't right yet.	Referring to their design drawing at the screen.

Example of teacher guidance toward theoretical reasoning

In order to see how the teachers help the students to improve their knowledge development and integration on theory and practice, we also need to look at the teacher guidance. For every school there is one example of an interaction which characterizes the pedagogical approach of the teacher in question.
The first example is one from school 1 in week 4 in which the teacher announces an ad hoc instruction for the next day after a discussion with students.

Example 7
school 1 week 4

	Utterance	Remarks
Teacher	… and then there is the the fact that we also need to calculate this length	Pointing at the drawing on the screen
Student	Sir, we were thinking that, if the wheels are right here, then there is 'lost space'. So we were thinking to put here another chair and then on the other side as well. That way two guys could sit on it.	Referring and pointing to a drawing on the computer screen in AutoCad.
Teacher	You can always try that. You can sketch that. But let me come back to what I just said. This length needs to be calculated at some point. How would you do that?	Pointing at the diagonal lines in the drawing of the frame.
Student	We have those here..	Looking for the papers with the sketches
Teacher	In the drawing? But can I also calculate those using maths?	
Student	But its on scale [the drawing], then you only have to....	
Teacher	Jaahhh, but you can't just draw everything at scale. Suppose that I have to make a big contruction of a bridge?	Interrupting the student
Student	That has to be on scale, otherwise if you do something wrong it collapses	
Teacher	But, is that on a scale of 1:2000 or of 1:200? I can calculate that. Help me remember, then we can discuss it next time [during a prototypelesson]. Because with Pythagoras' theorem... We will calculate it next time, because it's calculatable.	

This interaction shows that the teacher points the students to the role of mathematics in their drawing. He asks questions an thus tries to have the student come to mathematical operations. Subsequently he postpones the theoretical explanation to a moment when the whole group is present.

The second example of teacher guidance was observed at the end of the design process at school 2, when students are actually building the tricycle. In the example a student is busy drawing angles at a piece of wood the the help of the metal tubes that must be connected to each other. He is trying to draw, but cannot find a way to do it.

Example 8
School 2 week 6

	Utterance	Remarks

Teacher	I should not need to explain this. You need to go to the mathematics teacher.	
Student	He is not there now.	
Teacher	Why don't you do it in AutoCad?	
Student	AutoCAD isn't working (at the computer), otherwise I would have done it already.	
Student walks out of the classroom and returns a little later. He is still busy measuring the angles for sawing the tubes of steal at the right angle.		
Student	Sir, I measured the ange and it was.... [inaudible)	
Teacher	That's what I already thought, because it was 60/30/30.	Pointing at the angles that together form the complementary angles in a square
Student	Aahh, then you could have said that right away!	
Teacher	Certainly not.	
The teacher takes the ruler from the table on which the tubes of metal are sitting.		
Teacher	If you look at it from this point of view, I see 60/30/30	
Student	Yes.	
Teacher	So, that's what you have to learn to see.	

The teacher here is connecting estimation of angles to the mathematics that goes with that. It is about integrating subject matter knowledge to vocational knowledge.

Conclusion

The present research explores how the models functioned for the students in the simulated workplaces at school as reasons for action and how these reasons evolve over time and through guidance of the teacher. Teachers guided the students in a co-constructive way, assisting students in the reconstruction of collaborative models and subject matter knowledge by means of an on-going and reciprocal process. In contrast to a more traditional form teaching, in which knowledge, concepts and models are provided in the form of ready-made solutions, guided co-construction may lead to a better understanding of modeling. The research question was: how do models function for students in simulated workplaces at school as reasons for action and how do these reasons evolve over time and through guidance of the teacher?

It was found that models were used by students to plan further activities and by teachers to guide them during this process. Although it was observed that teachers tried to connect knowledge from academic discplines as mathematics and science as well as vocational knowledge to the practical design and construction process, students did express this in at a level that showed integrated reasoning . Most utterances that could be found were practical, some contained reasoning, but only a few utterances combined practical with theory and no utterances were found that showed reasoning with integration of subject-matter or vocational knowledge with practice. It was at school 2, where students presented their prototype for their peers, that utterances were found that contained both knowledge and practice.

Student reasons for action tend to become more practical toward the end of the process. This resembles what was found in earlier studies (Van Schaik et al., 2010b), that models dissapear in the process of desiging. It can be concluded that most reasoning in a design and construction process can be found around the time that studenst move from drawing to actually constructing. After that, the construction, not the desiging, is the core activity, thus students focus on practical issues. Only when aftward the students are asked to reflect on the process, as with the presentation at school 2, they again reason and explain and express their knowledge.

Discussion

We agree with Gresalfi (2009) that collaborative practices and the meaning-creating opportunities they afford are important for learning. However, Dutch pre-vocational education differs from other systems in that it has a dual focus, directed towards vocational knowledge and skills as well as on general codified knowledge derived from the academic disciplines. According to this view collaboration on authentic assignments alone is insufficient to integrate skills and disciplinary knowledge. The missing collaborative factor is the teacher, who is required to support students in relating practical problem solving to codified curriculum knowledge (Guile & Young, 2003; Van der Sanden, Terwel, & Vosniadou, 2000). The fact that workplace teachers at the schools in this study had backgrounds in the relevant academic disciplines might be taken to suggest that teachers in those classrooms used conceptual and pedagogical tools to integrate subject matter theory (Tynjälä, 2008). Also, students at the two schools used CAD software for their drawings. This software forces the students to model like designers, in ways similar to normal practice in their future occupations. In other words, with the support of academically trained teachers, the students' disciplined perception may have been enhanced, in the following two ways (Stevens & Hall, 1998). First, students assumed the role of workers in their discipline (vocation). Second, they learned to see the connection between practice and theory: they not only practised their vocational skills in the workplace, but were, in addition, trained to use the models as tools for problem solving both in vocational practice and in the academic disciplines that were reflected in the curriculum subjects. Further research will have to focus on the micro level to examine the enhancing effect of CAD software use on discipline perception.

Further research might confirm the teacher characteristics that Mercer (2002) found at well-performing primary schools. We refer here specifically to the assistance given by the teachers by which students are given greater insight into disciplinary problem-solving strategies. We have found that the teachers do try to integrate the subject-matter/vocational knowledge and the practice of designing and constructing a tandem tricycle. However, that did not lead to student utterances at level 4 and only at school 2 to utterances at level 3. The guidance of teacher may have to be both even more explicit toward subject-matter knowlegde, like the teacher at school one, meanwhile students may need to be pushed to also present their theoretical reasoning in a final presentation, like at school 2. That kind of teacher guidance may help students make sense of their experiences in relation to the knowledge codified in subject matter and in the practical domain. In combination with student reflection at a more theoretical level on their process, might therefore be instrumental in attempts to overcome the gap between theory and practice in vocational education (Bakker & Akkerman, submitted). A hybrid learning environment may be the form that connects student experience to codified knowledge (Huisman, De Bruijn, Baartman, Zitter, and Aalsma 2010; Zitter, De Bruijn, Simons, and Ten Cate 2011).

The present study suggests two factors that may improve student's reasoning and understanding of models: explicit attention for integration of knowlegde and practice by the teachers; reflection on the design process at the end. Further research will be required to examine the nature of teacher-student micro-processes and the tools used in problem-solving processes.

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Notes

1In this article pre-vocational education will be used to refer to the Dutch preparatory senior secondary vocational education,VMBO.

2The vocational workshops are the practice classes in which the skills and attitudes are practiced.

3 In VMBO students are divided among four 'learning tracks.' They differ in the theoretical level of the subject matter. The four levels are 'basic level' (lowest theoretical level), 'Staff level' (second theoretical level), 'mixed level' (intermediate level) and 'theoretical level'(highest theoretical level).

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NCOI – Brief introduction

NCOI is the largest private provider of governmentally accredited, high quality and easy accessible education programs in the Netherlands. The company was founded in 1996 and has become the Dutch market leader in providing professional education programs and training courses.

NCOI offers a comprehensive and growing portfolio of over 1,000 programs: i) accredited and certified education programs, ii) non-accredited education programs and iii) traditional subject-oriented skill training courses.

Over the last three years, the product offering was further broadened and strengthened by complementary acquisitions; Scheidegger (primary focus on MBO (intermediate vocational education) for private individuals), Compu'Train, Twice and Broekhuis (all ICT segment), completed with Vergouwen Overduin (high-end training institute) in the summer of 2012.

- NCOI provides education and training programs with a focus on professionals, mainly consisting of (accredited) open line MBO, MHBO, HBO (Bachelor) (higher vocational education) and Master programs;
- Scheidegger primarily focuses on private individuals, mainly serviced through accredited open line programs at intermediate vocational education level ('MBO');
- ICT Group provides vendor certified ICT training courses, primarily business-to-business;
- EVC provides assessment and recognition of prior experience by means of officially recognized certificates;
- Concept Uitgeefgroep and Broekhuis Publishing are publishers of educational books for both internal and external use;
- BCN operates multi-functional, high quality conference centers, facilitating NCOI and third party education and training programs.
- The education and training programs are basically marketed through two distinctive sales channels:
- Open line subscription; education or training programs offered on individual basis to professionals who meet official education requirements
- InCompany program (corporate accounts); any of the existing (open line) programs and/or 'made to measure' programs offered on an in-house basis to a group of employees selected by the customer