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How to bring a technical artifact into use: A micro-developmental perspective

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Abstract In order to understand how technical artifacts are attuned to, interacted with, and shaped in various and varied classrooms, it is necessary to construct detailed accounts of the use of particular artifacts in particular classrooms. This paper presents a descriptive account of how a shared workspace was brought into use by a student pair in a face-to-face planning task. A micro-developmental perspective was adopted to describe how the pair established a purposeful connection with this unfamiliar artifact over a relatively short time frame. This appropriation was examined against the background of their regular planning practice. We describe how situational resources present in the classroom—norms, practices and artifacts—frame possible action, and how these possibilities are enacted by the pair. Analysis shows that the association of norms and practices with the technical artifact lead to a contradiction that surfaced as resistance experienced from the artifact. This resistance played an important part in the appropriation process of the pair. It signaled tension in the activity, triggered reflection on the interaction with the artifact, and had a coordinative function. The absence of resistance was equally important. It allowed the pair to transpose or depart from regular procedure without reflection.

Keywords Appropriation · Enactment · Resistance · Plan construction · Shared workspace

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Introduction

Recently, there has been increased consideration in CSCL for the propositional nature of technical artifacts (ijCSCL Volume 7, Issue 2) in that technical artifacts make opportunities available for collaboration and learning that suggest a certain use, but do not causally determine learning activities or outcomes. It is argued that technology is a composite of the technical artifact and the practical actions of its users. Underpinning the argument is the assumption that a technical artifact itself is underdetermined, and that its use and effect as a technology take shape when brought into use in particular activity contexts (either by an individual user or in collaboration). It is maintained that a technical artifact carries a potential for action that becomes available when learner(s) and artifact connect, and that the availability and realization of this potential is relative to the one(s) who interact(s) with the artifact and to the socio-cultural context in which this takes place (Overdijk et al. 2012). This is not simply saying that learners do different things with artifacts, or that they may do things differently. Underlying is a more fundamental concern: There is agency present in both the learners and the technical artifacts they are presented with (Pickering 1993). The artifact-in-use, consequently, is contingent on the interaction of these agents and it is—to greater or lesser extend—shaped by both of them.

The task that lies ahead is to further detail how technical artifacts are brought into use, or rather, how they are attuned to, interacted with, and shaped in various and varied educational practices. It is necessary, we argue, to give precise accounts of how the uses and effects of particular technical artifacts are constructed within the contexts of particular classrooms. This is important also because classrooms—such as the one in this study—are increasingly open and heterogeneous environments wherein learning is often no longer centrally arranged. Instead, the learners themselves are at the centre of their own learning process, and are expected to shape their own learning activities in a trajectory that fits with their personal abilities, knowledge, and needs. To adapt to these new kinds of pedagogies the current breed of technical artifacts shows increased flexibility.

In this paper we adopt a micro-developmental perspective on the use and effect of artifacts (Rabardel and Bourmaud 2003; Engeström 1987). We maintain that use and effect are constructed within situated classroom practices, involving multiple resources that are drawn from and integrated interactionally (Stahl 2013; Danish and Enyedy 2006; Enyedy 2005). In order to understand how a technical artifact is brought into use, we examine how these multiple situational resources frame possible action, and how the learners enact these possibilities.

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Goal and relevance of this study

The goal of this study is to provide a descriptive account of how a technical artifact is introduced and brought into use in an existing classroom practice. In specific terms, we address the appropriation of a digital shared workspace by a student pair who works jointly on the construction of a project plan. We examine how this shared workspace is brought into use against the background of their regular planning practice. Appropriation, as we understand it in this context, implies a tension between the artifact-as-used and the intentions invested in the artifact by its designers (Overdijk 2009; Carroll, et al. 2002; Dourish 2001; Orlikowski 2000; DeSanctis and Poole 1994; MacKay and Gillespie 1992; Norman 1988; Pinch and Bijker 1987). In this paper we present some insights on the way in which this tension comes to arise, how it develops within a small time frame in the context of joint activity, and how it is eventually resolved through a complex set of negotiations.

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Theoretical perspectives

From artifact to artifact-in-use

Technology does not exist independent of its use, instead it takes shape when used in particular activity contexts. This idea is not new to CSCL (see LeBaron 2002), and it has been pursued in sociology (MacKenzie and Wacjman 1985; Bijker, Hughes, and Pinch 1987) and organizational sciences (Orlikowski 2000, 1992) since the 1980's. It rests on the assumption that technology is a composite entity that consists of technical artifact(s) and practical knowledge and action, as instantiated in activity. It assumes that technology is the result of an association of the two—human action and artifact—wherein both may exercise agency: Human agency, the intentions of the users of the artifact, and material agency, the intentions of the designers invested in the artifact. The challenge is to account for both, without unnecessarily prioritizing one over the other. One could rephrase this as follows: CSCL technology results from an interaction of the intentions that are invested in the artifact by instructional designers and the intentions of the learners that perform actions upon the artifact. In this way, utilization of a technical artifact can be seen as a process of social construction that is generated from a dialectic of resistance and accommodation between human agency and material agency (Pickering 1993).

How do the learners and the artifact become purposefully connected? A useful starting point is the affordance (Gibson 1979; e.g. Kreijns and Kirschner 2001; Suthers 2006). This concept proposes that an artifact carries a potential for action that becomes available when learners connect with it. The particular opportunities that become available are commonly assumed to be relative to the needs and abilities of the learners. Learners enact the opportunities they perceive and thereby realize part of the action potential that is carried by the artifact. The affordance is appealing because it underscores personalized perspectives on CSCL and an active role of learners in working with technology. However, in the context of appropriation of new and unfamiliar technology its explanatory value is limited (Overdijk et al. 2012) because it does not capture development.

Instrumental genesis

A framework that is more elaborate with respect to appropriation, and compatible with the affordance, is brought forward with the theory of instrumental genesis (Lonchamp 2012; Ritella and Hakkarainen 2012; Rabardel 1995). Here, the artifact-in-use is a heterogeneous entity—referred to as instrument—that emerges from the interaction of the learners with those artifacts. The use and effect of the artifact results from the interaction and (gradual) association of the two. The process by which an artifact is brought into use as the development of a hierarchical activity system (Rabardel and Bourmaud 2003; Rabardel). During this development the artifact and relevant (cognitive) utilization schemes become associated with each other and form a functional system (Kaptelinin and Nardi 2006). An instrument consists of an association of an artifactual component-an artifact, a fraction of an artifact or a group of artifacts-and a scheme component (in the Piagetian sense of the term: Piaget 1964). Rabardel and Bourmaud suggest that when agents bring an artifact into use, they call upon sets of routines and procedures that have developed around previous use of the specific artifact at hand, or, when the artifact is unfamiliar to them, upon those that are associated with similar or otherwise related task-artifact configurations (Rabardel and Bourmaud 2003; Rabardel 1995). For example, in the case of planning, some of the routines and procedures that have developed around paper-and-pencil plan construction may also apply to plan construction with another,

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new type of representational artifact, depending on the similarities and differences between that particular artifact and the paper-and-pencil situation. According to Rabardel and Bourmaud, the new representational artifact is either (partly) operated from a pre-existing set of utilization schemes, or when these do not apply, from an adapted version of the existing set. This transposition of utilization schemes, when successful, allows for the generalization of 'ways of doing' from one task-artifact configuration to another. If such transposition is not possible, utilization schemes are adapted or the artifact itself is adapted.

Instrumental genesis is seen as a progressive movement along hierarchically organized, interrelated dimensions. On a personal dimension, the physical connection that each single learner entertains with the artifact, and the ability to act consciously on basis of personal needs, goals, and expectations. On a collective dimension, the coordination and fine-tuning of the interaction with the artifact between multiple learners in order to achieve a common goal. It suggests furthermore that the object of activity, or in Rabardel's terms 'the orientation of mediation', may shift throughout the development from artifact to artifact-in-use.

The theory predicts that when learners are confronted with a new artifact, they initially focus on the interaction with the artifact in order to perform basic acts. In activity terms, their action is oriented towards entertaining a physical connection with the artifact and towards manipulation of its interface, whereby the artifact itself is the object of activity, and knowing how to produce basic acts is the motive. Once a leaner has mastered sufficient basic acts, that is, knows how to manipulate the interface, his or her attention shifts towards the object for which the artifact is a means of performance. It shifts, in other words, from mastery to utilization. This is when basic acts are coupled to a purpose, aimed at the fulfillment of a task-related motive (what Rabardel and Bourmaud have termed the establishment of 'an instrumental act'). In this process there are potential sources of conflict and tension. Different learners, when confronted with the same artifact, may perceive and enact different opportunities. In order to collaborate they will have to arrive at a mutually agreed use. Coordination and mutual fine-tuning is then crucial to achieve a common goal. Another potential source of conflict and tension is the transposition of ways of doing from one task-artifact configuration to another. Existing routines and procedures can be in conflict with the 'spirit' of the artifact (a term coined by DeSanctis and Poole 1994)—the intentions that are invested in it by its designers—and may be counterproductive.

Classroom practice and situational resources

When an artifact is introduced in the context of existing activity, then this context is important to understand how the artifact is brought into use. The use of artifacts is situated in practices (Hall 1996; Enyedy 2005) and motivated by routines and procedures that are part of those practices (Cobb, Stephan, McClain, and Gravemeijer 2001). Classroom studies indicate that the use of an artifact is an interactional achievement whereby learners draw on, and integrate multiple situational mediators (Medina and Suthers 2012; Streeck et al. 2011; Danish and Enyedy 2006; Enyedy; Goodwin 2000; Roth 1996). These mediators, some of which are material and some immaterial, elaborate each other and are interpreted in relation to each other (Roth; Goodwin). They include resources for communication as well as classroom norms, procedures and available (technical) artifacts. The practical knowledge part of these resources could perhaps be traced back to Rabardel and Bourmaud's cognitive scheme components, but these schemes are not available to us as researchers. Following the study by Cobb et al., three elements of classroom culture are likely to frame the learner's situated actions (Greeno 1998; Suchman 1987): The social norms of the classroom, the social norms that are specific to the task at hand, and the practices that have formed around this task. Applied to our context of plan

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construction, these three mediating factors can be described as follows: Social norms refer to taken-as-shared ways of interacting and participating within the classroom, such as the need to justify solutions or accepted modes of collaboration. Socio-planning norms refer to those norms that are specific to plan construction, such as what counts as a valid simulation of a planning decision. Finally, planning practices refer to specific ways in which procedures and artifacts are used to achieve planning goals (after Cobb et al.). Together, these norms and practices contribute to the frame from which the technical artifact is enacted.

Through enactment the use and effect of the artifact take shape. The term enactment emphasizes that people respond to the environment they face, and at the same time through their performance produce part of the environment (see for example Weick 1995; Bansler and Havn 2006; Orlikowski 2000). Enactment, as Weick (ibid.) has put it, has a reactive and a proactive dimension. Reactive in the sense that human action is framed within the constraining and enabling conditions of the environment, and proactive in the sense that through their actions humans produce new conditions for future action. Although it is not our aim to band with Weick's theory, we use the term 'enactment' with a similar intention: Learners' practical actions are framed within the constraining and enabling conditions set by situational resources, while with their performance learners produce new conditions and resources that shape future actions (Overdijk and Van Diggelen 2008).

Plan

A digital shared workspace is introduced to support joint plan construction. We address the appropriation of this artifact as a relatively short-term situational process—a micro-development (Rabardel and Bourmaud 2003; Engeström 1987). We assume that the learners' practical actions are framed within the constraining and enabling conditions that are set by the artifact as well as by the norms and practices of the classroom. We take it that the learners draw from these situational resources through enactment. Since the artifact is introduced into a pre-existing planning practice, it is possible and likely that existing norms and practical procedures become associated with the artifact and influence they way it is brought into use. It is also possible that transposition of norms and practices lead to tension and that those new practical procedures have to be invented.

We approach appropriation as micro-development by pursuing these questions: What is the nature of the norms and practices of regular planning; to what extent and how do these norms and practices become associated with the artifact, and how does this develop over a relatively short time span?

Methods

A case study approach (Yin 2003) was chosen as the most appropriate research method, given the need for in-depth understanding and the explorative character of the study.

Educational context

The case study was carried out within a secondary vocational school. The school management had initiated a pilot program that induced a transition from a more traditional form of education to a form in which learners perform project work in pairs, relatively independent of the teacher. This new form contained far less structure than the traditional way of working. In the pilot

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program the students had to plan, carry out and evaluate their project themselves. The school was exploring artifacts that could fit with the program, and in this context they introduced the shared workspace as a planning aid. At our point of entry the pilot program was running for approximately four months. Our study began one project (for two weeks) before the introduction of the shared workspace in the classroom. We examined the two consecutive projects, one in which students were engaged in regular plan construction (the Flower project), and one in which the shared workspace was introduced to support the planning process (the Kitchen project).

Participants and course

The class that participated in our study consisted of 12 students (6 pairs) aged 14–15 years at the third year level. Over the duration of the school year they had to complete several projects. Each project lasted two weeks, and every two weeks a new project began. The projects addressed different themes, but always covered the domains communication, technology and civics. With each project the pairs were presented with a syllabus that contained a series of assignments organized by domain (see appendix 1). At the start of each project the pairs were expected to construct a plan that described in detail the tasks that had to be carried out for each day of the project.

The planning problem

The planning problem requires that the students identify task requirements, sub-tasks, and external constraints that could influence their plan, and to translate this problem representation into an ordered set of planning decisions. The translation from problem representation to plan construction requires, among other things, projection of the consequences of particular planning decisions (Pea 1982). For example, students had to make estimates of the time that would be needed to complete a particular part of the plan, and had to take into account interdependencies between different parts. Plan construction also requires critical evaluation and possibly revision of these decisions (Pea). The planning problem is organized around some form of shared representation—either on paper or on screen. This representation should enable the students to discuss the problem and should capture their planning decisions in terms of tasks, sub-tasks, duration and the order of implementation.

Methodological approach

We chose to zoom in on the appropriation process of one pair. We used a qualitative descriptive method to construct a case study, in which we combined several sources of data. A case was defined as the activities and products of the pair during the planning phase of the two consecutive projects. The first part of a case pertains to the regular mode of plan construction (first project) and the second part pertains to plan construction with the shared workspace (second project).

Data

In the first part of our study we collected data about the norms and practices of regular planning via interview, observation and a completed project plan. Prior to our entry in the classroom we interviewed the teacher. At entry we observed the planning session and made field notes of our observations. We also collected the project syllabus that contained the

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description and assignments of the project. In the second part of our study we were present in the classroom when the shared workspace was introduced and brought into use. Again we observed the planning session and made field notes of it. We collected the syllabus and the final plan. In addition, we made audio recordings of the pair, and we saved a replay of their actions in the workspace. Finally, we interviewed the pair about their experience (this interview was also an important source of information about the norms and practices of regular planning).

Analytic approach

The two parts of the case were subjected to a descriptive analysis. The analysis of the first part serves to contextualize the second part. The first part focuses on identification of norms and practices (Cobb et al. 2001) that were established in the classroom with respect to planning. We identified planning practices through observation, via the interviews with the student pair and the teacher, and through the constructed project plan. The teacher interview and the constructed plan were our sources of information about social planning norms.

The second part of the case focuses on how the workspace was brought into use. Analysis here has a dual focus. First, it examines representational actions, defined here as the observable acts in the workspace that learners engage in as they are creating their project plan (e.g. placing a line or adding a feature). Complementary to this it examines those aspects of the learners' talk that were oriented towards a purposeful and coordinated use of the workspace. In practice, this talk and representational actions overlap and mutually elaborate one another.

We analyzed the data in three steps. In the first step we transcribed the audio recordings of the pairs into a protocol that included all utterances, the time of the utterance, and the speaker. With aid of the replay we then added the actions that took place in the workspace onto the timeline. The replay gives a time-stamped, frame-by-frame representation of the actions that took place in the workspace (notably, our transcription did not take overlap of talk and action into account). We used the first step to organize the data and to take a first pass at understanding what was going on. In step two we selected relevant episodes for further analysis. An episode corresponds to a duration of coherent activity demarcated by the students' own behavior (Roschelle 1992). We selected all episodes that contained talk and/or actions oriented towards construction of the project plan. In the third step we constructed a qualitative description of the selected episodes.

Analyses

In the first part of this section we examine the norms and practices of regular planning with the Flower project. In part two we examine how the shared workspace is brought into use in the Kitchen project. The names of the pair are Lucas and Oscar (these names are pseudonyms).

Part 1: Making a plan for the flower project

We entered the classroom on the first day of the Flower project, were we observed how Lucas and Oscar constructed a project plan. Both sat at a table and read the syllabus. They briefly reflected on the content of the syllabus and started drawing up a plan. One of them drew the planning decisions on paper and the other read from the syllabus as a reference (see Fig. 1 for an impression of this setting). It took them about 30 min to sketch out this initial plan. After this they moved to a computer where the plan was brought into a spreadsheet program. Lucas and Oscar sat jointly behind the computer with one of them typing the initial decisions into the

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Fig. 1 Pair, similar to Lucas and Oscar, working on their plan for the flower project

program, and the other reading from the initial plan and the syllabus. This took them another 25 min to complete.

Below is an excerpt of the interview we held with Lucas and Oscar at the end of the second project (when they had already worked with the shared workspace). In this excerpt they talk about the procedure of regular planning and their use of artifacts.

Researcher How did you like working with this tool?

Oscar I think it works fine. It's useful. Instead of writing everything down, or having to make your own squares in Excel.

Researcher How do you normally do it, making a plan.. you mentioned Excel?

Lucas On paper.

Researcher On paper?

Lucas Yes.

Researcher So, first on paper, and then in Excel. You also do that with the two of you?

Lucas Nah. Actually only one at a time can sit behind a computer.. But sometimes we just sit behind it with the two of us.

Researcher That's like a rule that you have, that only one at a time can sit behind a computer?

Lucas Yeah.

Researcher But you have to carry out the project with the two of you.

Oscar So we first make a planning on paper..

This gives us a general idea about the procedure and the use of artifacts. The teacher confirmed this idea. The students are accustomed to pass through two stages-as the teacher had

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instructed them at the start of the pilot program: First, the pair studies the assignments in the syllabus and sketches out an initial plan with pen and paper; second, the decisions are brought into a computer program—usually in a spreadsheet, and sometimes in a word processor. In addition, there is a rule where only one student at a time can sit behind a computer, meaning that the students have to decide beforehand who will manipulate the mouse and keyboard.

We can make some inferences about the planning practice: (P1) the pair passes through two stages, where a paper-and-pen representation of the plan from the first stage serves as input for an on-screen representation in the second stage; (P2) in both stages, the pair works on the basis of a task division, whereby one of them manipulates the representational artifact and both of them comment on this manipulation.

Ideally, according to the teacher, the final plan should separate and capture distinct requirements, and it should describe these requirements in terms of tasks, sub-tasks and duration, and in order of implementation-distributed over the two weeks of the project. Inspection of Lucas and Oscar's plan tells us that it does not meet these specifications. During the paper-and-pencil stage, instead of indentifying task requirements, sub-tasks, and external constraints, Lucas and Oscar basically added the assignments as they were presented in the syllabus in undifferentiated form into a tabular representation (i.e., in rows and columns). The first column describes the assignments, following the exact order and domain-wise grouping of the syllabus. The second column contains an estimation of the time that would be needed to complete the particular assignment. The third column indicates when a particular assignment is completed. The plan does not contain interdependencies between the different parts. Implementation order of the assignments is implicit, and it does not evidence any simulation of consequences of planning decisions. The final on-screen representation made during the second stage is an (almost) exact copy of the initial paper plan (see appendix 2 for the final plan, made in a spreadsheet). The teacher confirmed that this type of representational form is common in the classroom. In his words they "simply looked 'what does it say here' (in the project syllabus) and 'how can we get that into the program'." The teacher tells us that this observation fits with a general lack of critical thinking in the classroom. On inspecting the final plan the teacher remarked that he could tell that the students do not know when they will be able to do what. "They talk about the business letter (third assignment under communication, appendix 2) while they can only do that at the end of the project. Because they will only have the necessary information at the end of the project."

This gives us some additional information about procedures and the use of artifacts. We can infer about the planning practice that: (P3) in both stages of the planning process the pair constructs a plan with a similar representational form, that (P4) consists of a tabular representation whereby assignments are implemented following their description and organization in the syllabus; this representation does not contain interdependencies between tasks and implementation order is implicit.

It also tells us something about the socio-planning norms: (P5) the pair does not engage in a real problem representation. Instead of simulating, evaluating and revising planning decisions, they stick with the specification and following order of the assignments as they are presented in the syllabus. To them, this is an acceptable solution to the planning problem.

Part 2: Bringing the shared workspace into use

On the first day of the new project Lucas and Oscar were introduced to the shared workspace: A networked tool designed to support joint representational activity in face-to-face settings (Fig. 2). The shared workspace enables representational acts via a notation scheme that supports specific contributions. A student can select a card from the notation scheme and

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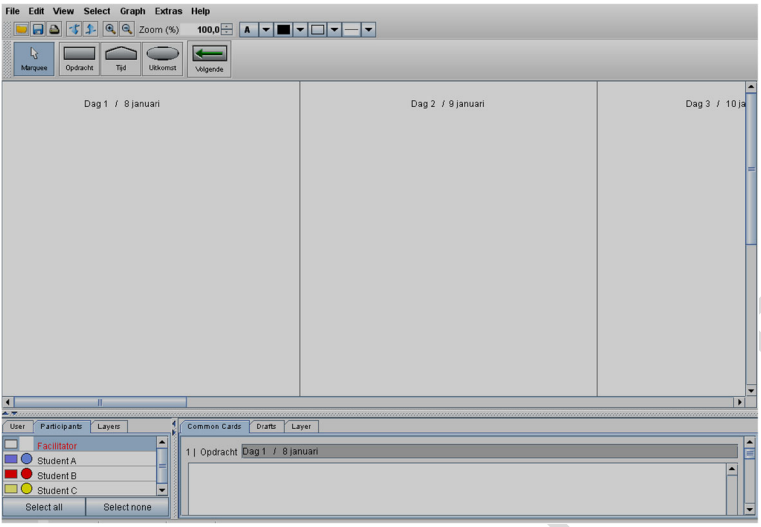

Fig. 2 Shared workspace with notation scheme and first three of the predefined columns

add it to the drawing space. That student can then add a text label to the title space of that card. By double-clicking on the card a comment window appears, where the student can further elaborate his contribution. Students can act simultaneously in the drawing space. Both students can read and move the cards through the drawing space. Once a card is placed in the space it can be associated to other cards by linking or grouping. For the Kitchen project the notation scheme contained three card types, 'task', 'outcome' and 'time', and the possibility to link cards. The drawing space contained a predefined structure: A division into ten columns, whereby each column was labeled with a date, representing one day of the project. These features were meant to provide representational guidance (Suthers and Hundhausen 2003), by promoting a specification of (sub) tasks, duration of the tasks, and dependencies between tasks (via the notation scheme), and a specification of implementation order (via the predefined structure in the drawing space). We refer to these features as soft constraints, they suggest or invite a certain use.

The teacher briefly explained the general principle of the workspace to Lucas and Oscar. He explained that they could use the workspace to construct their project plan, that they could both manipulate the representation of the plan from their personal laptop, and that their contributions would be visible on both their screens. Lucas and Oscar sat directly opposite to each other so they could construct a representation in the drawing board and communicate verbally at the same time. Prior to the session they read the assignments in the project syllabus (see appendix 1). They did not have any hands-on experience with the shared workspace. At the start of the activity both explored basic acts. They figured out how to submit a card, how to label it, and how to move cards through the drawing space. Then they explored the more advanced basic acts; that is submitting text to the comment window of the card and applying a link between two cards. Our detailed report starts where Lucas and Oscar had mastered the basic acts.

In the analysis below we trace out how the planning norms and practices that were identified in the first part of the case (P1–P5) informed appropriation of the artifact. The analysis shows how some norms and practices are adapted or departed from, and how new procedures (NP) are introduced. The analysis is presented in two steps. In the first step we

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present for each episode the actions and utterances from the protocol as sequences oriented towards the construction of a project plan (the full protocol can be found in appendix 3). In the second step we describe appropriation as a series of enactments whereby norms and practices and the artifact become gradually associated.

'Oh, you do it like that..' (Episode 1)

The first episode starts where Oscar had placed a 'task' card in the drawing space and labeled it 'communication' [97–98]. He placed his card in the first column, on the first day of the project. There under he placed a card that indicated the first assignment in the communication domain- to develop a project plan-and labeled it 'project plan in workspace' [99–100] (Fig. 3).

By placing a card with the label 'communication' at the top of the first column, and by adding a planning decision under it, Oscar initiates the construction of the representation. Lucas observes Oscar's actions on screen and asks [101: Put everything underneath communication?]. Oscar confirms Lucas's inference to list everything under the'communication' card, and proposes a task division following his example to list the assignments under the domain they are a part of [102: Yes, under communication, if I do that one, then you can do the next]. Lucas accepts this proposal [106: 'Oh, you do it like that..OK'].

Oscar's enactment of the technical artifact appears to be informed by a procedure from regular practice: To organize the assignments according to the domain that they are part of, and to list them following their description and organization in the syllabus (P4). Oscar used a 'task' card from the notation scheme to represent the domain, and a 'task' card to list an assignment under this domain. He furthermore hinted towards a task division whereby both contribute to the drawing space simultaneously. This proposal, to enact the opportunity of simultaneous access by working on a different part of the plan at the same time, suggest a new procedure (NP1), and is a deviation from regular practice (P2). These enactments are referred to only indirectly, and they remain implicit in the dialogue.

(Episode 2)

In the episode that follows the pair keeps with the suggested task division. Both work simultaneously on a part of the representation (NP1). Oscar continues his list of communication assignments in the first column, Lucas starts to list in the second column (Fig. 4). They use only the 'task' card from the notation scheme. Oscar inscribes some specifications with the assignments (subtasks) in the comment window of his cards. These specifications are not directly visible (the card had to be double-clicked to see the contents of the comment window). There is no discussion about planning decisions. The students keep with the order of the assignments as presented in the syllabus (P5). The semantics of the 'soft' constraints that are produced by the drawing space (i.e., the predefined time-categories) and the notation (i.e., the

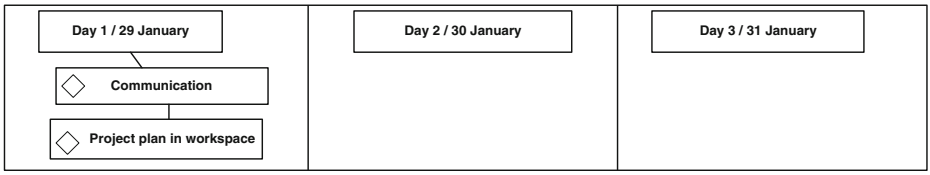

Fig. 3 The workspace at episode one

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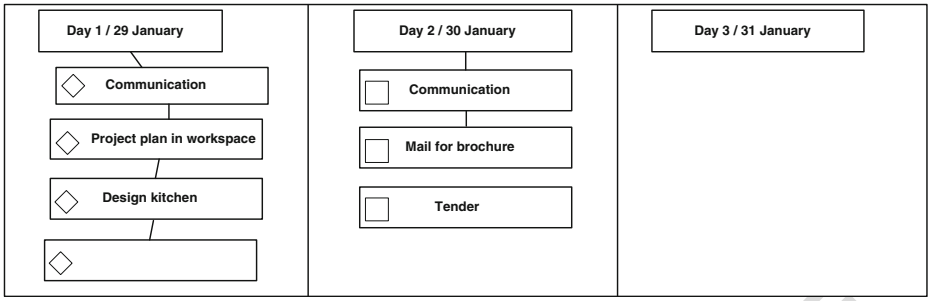

Fig. 4 The workspace at episode 3

three card-types, 'task', 'time' and 'outcome') do not come into play. The predefined columns structure the representation, but implementation order is implicit.

'What's that a part of?' (Episode 3)

The following episode is initiated with a question by Lucas [141: What's kitchen design a part of?]. Oscar's answer [142: That's part of technology] triggers Lucas to respond [143–144: Then we should perhaps leave communication out. But do only the things that we need to do on that day].

Lucas's question appears to address an issue of problem representation, but is in fact a rhetorical question, concerned with the representational form of the plan. Oscar had placed the 'design kitchen' assignment under the heading 'communication', while it is in fact part of the technology domain (Fig. 4). Lucas noticed this as a deviation from the procedure they had both agreed to follow in the first episode (P4). He appears dissatisfied with this inconsistency. He draws attention to the contradiction, and suggests a solution to overcome it. The new procedure, suggested by Lucas' proposal to 'leave communication out' would be to indicate the assignments on a specific day, without reference to the knowledge domain that they are a part of (NP2).

'But, we are now, eh…per part…' (Episode 4)

Oscar does not respond to Lucas' proposal. Two minutes later he says [156: Where do we put technology?]. Lucas himself had already deleted the 'communication' card he had placed in the second column (Fig. 4). Oscar attempts another solution. He adds a card labeled 'Technics' and places it above the kitchen design assignment [158]. Then he deletes the 'Technics' card and types 'technical drawing' in the card with the 'design kitchen' assignment, indicating the domain in the card instead of above it. A few seconds later he seems confused [165: But, we are now, eh.. per part..]. He moves the 'design kitchen' card to the third and empty column in the drawing space. Lucas moves the 'design kitchen' card back to the first column, and adds a card labeled 'technology' above it (Fig. 5). He concludes [170: So we'll also get communication].

By placing a technology assignment in the first column Oscar created competing constraints on the representation: the first column now signified 'dedicated to communication assignments' and 'tasks planned on Monday'. Oscar tried to resolve the inconsistency. Combining two domain labels in one column did not satisfy him. He decides to move the technology assignment away from the first column in order to regain consistency. Hereby he prioritizes the existing representational convention over a deliberate planning decision. He ignores Lucas's proposal. Lucas, who had noted the inconsistency already in the previous

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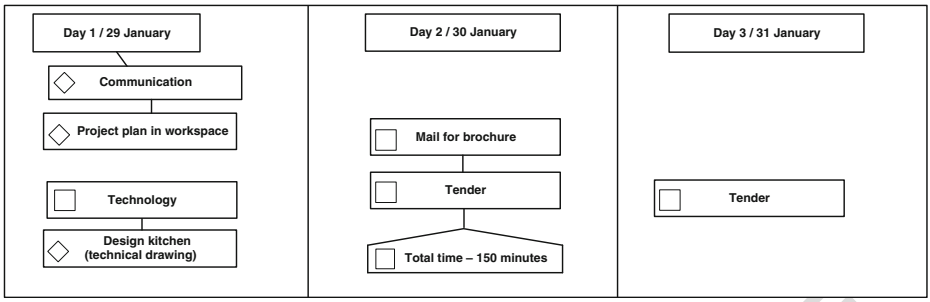

Fig. 5 The workspace at episode 4

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episode, responds by implementing a solution that combines the two principles: Planning assignments per day and adding the corresponding domain with each (set of) assignment(s) (similar to Oscar had done earlier and had then rejected). Lucas integrates the existing procedure with the new one (P4 + NP2).

'We'll just do planning for a day' (Episode 5)

In episode 5 Oscar restates his intention with technology assignment [242]. Lucas, in response, asks him what domain that assignment belongs to [243-244]. He proposes again to abandon the domain labels all together [246]. Oscar responds with [247: No, we'll just do planning for a day, not for a course, we'll just…shall we do that?]. This seems compatible with what Lucas had just proposed, so Lucas repeats his proposal [248]. Instead of complying, Oscar formulates an alternative that combines the proposal to plan for a day with the established convention to indicate the domain [249–250: I think we'll just have to plan what we do on that day. And then we put above there what it is, eyh?]. Lucas agrees.

In this episode Lucas and Oscar reiterate their negotiation from the previous episodes. Lucas attempts to depart from the existing procedure (P4), by suggesting to omit the domain labels. Oscar considers the fact that his planning decision requires a departure from procedure—where he seemed reluctant to do so before—and proposes the same solution Lucas proposed earlier (NP2). In his next utterance he elaborates NP2 by integrating it with P4, precisely as Lucas had implemented in the previous episode (P4 + NP2). After this, Lucas and Oscar do not address procedure. In the remainder of the activity they are focused on problem representation and plan construction, the actual content of the plan. Figure 6 shows a fragment of the final project plan.

Micro-development of activity

The students explore several distinct, hierarchically interrelated dimensions in the activity: The production of basic acts (prior to the first episode), the construction of a representational form, making planning decisions, and coordination of both the use of the artifact and the joint task. Their orientation shifts several times within a relatively short time frame. These shifts imply an upward or downward movement in the hierarchy of micro-development.

In the first episode Oscar's orientation shifts several times. First he is oriented towards construction of a representational form; then his orientation shifts to making a planning decision, and then it shifts to coordinating the use of the artifact with Lucas. In the second episode both students are oriented on making planning decisions. When in the third episode

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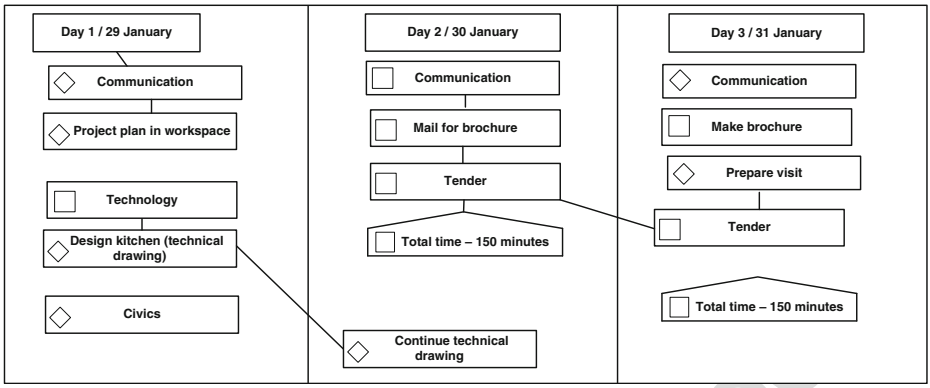

Fig. 6 Fragment of the final plan

Lucas notes a contradiction, his orientation shifts from making planning decisions to construction of the representational form. In hierarchical terms, his orientation shifts downwards. In the episode there after Oscar's orientation shows a similar downward shift. The downward shifts appear to occur where the students experienced resistance from the artifact. When the inconsistency is resolved (or appears to be resolved), orientation shifts upwards, and both are again focused on making planning decisions. The upward shift occurs, in other words, where resistance was accommodated.

Resistance triggered reflection and led to adaptation of an existing procedure. Other procedures departed from without resistance or reflection. Out of the five norms and practices that we identified as central to regular planning, three were departed from: The division in two stages, whereby the paper-pen stage serves as input for the on-screen stage (P1), and consequently the similar form of the plan in these stages (P3). Also the task division was departed from, whereby one student manipulates the artifact and both comment on this (P2). These procedures were departed from without reflection. In the case of P1 (and P3), this is perhaps not so surprising, since the students found themselves already working on-screen. Departure of P2 was a different case. Enactment of the opportunity of simultaneous manipulation resulted in a new procedure (NP1), whereby the two students worked on a different part of the representation at the same time. They could have enacted the opportunity to take turns, whereby one would manipulate the representation at a time—perhaps more similar to existing procedure. We return to this point in the discussion below. We have seen how P4 was adapted and integrated with a second new procedure, resulting in (P4 + NP2). The one element of regular planning that did not change was the norm (P5) to stick with the specification and order of assignments in the syllabus, and to not engage in a real problem representation.

Discussion

In this study we analyzed how a technical artifact was brought into use within an existing classroom practice. We addressed the appropriation of a digital shared workspace by a student pair who worked jointly on the construction of a project plan. The process of appropriation was described against a background of their regular planning practice. By zooming in on one pair we provided a detailed description of the way in which enactment of the artifact was contingent on interplay of situational resources. At the same time this points to a limitation of our study: single case analysis offers a small basis for generalization.

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The conceptual framework we adopted combines elements of affordance theory (Gibson 1979), instrumental genesis/activity theory (Rabardel 1995), and representational practice (Hall 1996; Enyedy 2005). We took the general premise of affordance as a point of departure: The artifact makes action opportunities available that are relative to the needs and abilities of the ones who work with it. But the notion of affordance alone does not explain appropriation (Overdijk et al. 2012). We adopted a micro-developmental perspective—based on instrumental genesis—to illustrate how classroom norms and practices inform the enactment of opportunities, and how appropriation develops—at least during the early stages that we studied. Our study shows that enactments may change during appropriation, that it is contingent on norms and practical procedures, and negotiated socially. We refer to our approach as micro-developmental because we examined appropriation over a relatively short period of time. We followed Rabardel and Bourmaud (2003) in conceptualizing the process by which an artifact is brought into use as the development of a hierarchical activity system. In this view, the artifact becomes gradually associated with cognitive schemes for utilization to form a functional system. In our framework we focused on the association of the artifact with situational resources (norms and practical procedures), rather than taking up the notion of utilization scheme. We focused on norms and practical procedures because the nature and content of cognitive schemes are not available to us as researchers. We combined, in other words, the framework of instrumental genesis with a situated approach to representational practice (Enyedy 2005; Roth 1996; Hall 1996).

Resistance and accommodation

Planning norms and practices (Cobb et al. 2001) were important situational resources in regular planning. Norms and practices more or less set the 'attitude' with which the students approached the planning task. Planning practices specified practical procedures to collaborate, utilize artifacts, and construct a representational form. Planning norms set the standard for what made an acceptable solution to the planning problem, and for what made an acceptable level of collaboration. With its introduction, the technical artifact became an important resource as well. Some of the norms and practices from regular planning became associated with the artifact; others were departed from. This association was not straightforward.

Important enactments took place at an early stage, and seemingly without reflection. When one of the students produced (part of) the regular representational format in the drawing space, both accepted this as a way to go forward. This concurs with Bowers, Cobb, and McClain (1999), who found that where learners work together relatively autonomous, routines and conventions tend to remain implicit, and recognizable practices are taken as self-evident. Still, (almost as an unnoticed by-effect) the pair departs from the task division whereby one of them manipulates the representational artifact and both of them comment on this manipulation—a procedure of regular practice. The enactment of the opportunity of simultaneous access results in a new procedure that is not a recognizable practice at all: the two students were working on a different part of the shared representation at the same time. It seems as if this enactment took place unreflectively—like an affordance, and apparently it did not cause substantial resistance. It has to be noted that the collaboration of the pair in our study was perhaps not as tight as it could have been. Here we have to take into account the specific setting of our study. The two students manipulated the shared representation from their own laptop, while being seated directly opposite each other. Most of the time their attention is focused on-screen. This is quite a challenging setting that requires a high degree of coordination. Given the fact that the pair is not accustomed to engage in a real problem representation, and that 'loose' collaboration is an acceptable standard to them, their task division may have simply seemed evidently efficient to both of them.

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Throughout the larger part of the appropriation process, a tension was present that had to be resolved. Our analysis shows how the association of a practical procedure from regular practice with the artifact led to an inconsistency in the activity. It leads to incompatible constraints on the representation: a contradiction of 'soft' constraints produced by the artifact and constraints produced by the representational convention. This contradiction surfaced as resistance, and triggered downward shifts in the hierarchy of micro-development, until the contradiction was resolved. The downward shift focused attention away from performing the task and towards enactment of the artifact. Miettinen (2001) points out that when people engage in practical action with artifacts, tension in the activity is experienced as resistance from these artefacts. In this sense resistance fits with the notion of disturbance that results from internal contradictions within systems of activity (Engeström 1999). This resistance is what triggers development of activity. Also in the model of situated action put forward by Suchman (1987), resistance or disturbance in artifact-mediated activity causes users to analyze their interaction with the artifact and to formulate rules or procedures. Following these similarities between the role of resistance in Leont'ev's model and Suchman's model, we can characterize the downward shift in the hierarchy of micro-development as a breakdown: a disruption in the functioning of things that forces one to adopt a more reflective stance toward the activity (Koschmann, Kuutti, and Hickman 1998). Accommodation of the resistance lead to an upward shift—a progressive step in the micro-development of the planning activity.

The pair accommodated resistance by integrating the existing procedure with a new procedure. They achieved this through a complex set of negotiations that combined direct manipulation of the artifact and verbal referencing to the procedure. It is not uncommon that the introduction of a representational convention leads to tension between opportunities and constraints (Enyedy 2003; 2005). The negotiation that followed is also congruent with other studies. Danish and Enyedy, similar to our study, found that the importance given to a constraint in representational practice, and its prioritization, is negotiated within ongoing activity (2006).

Conclusion

The introduction of the technical artifact in the classroom posed a challenge to the pair. They were challenged to bring it into use while they could not fully rely on their regular planning procedures. They did not discuss a strategy for utilization beforehand, nor did they project the consequences of choices that were made—mostly early and implicitly—during the process of appropriation. Enactment of opportunities and construction of the project plan occurred simultaneously and incrementally. Where the students did not experience resistance from the artifact, they did not reflect on their enactment or on the procedures that informed it. Reflection was triggered where resistance did occur. In our case study resistance signaled tension in the activity, triggered reflection on the interaction with the artifact, and—because of the specific setting—had a coordinative function: It focused the students' attention on the same problem. The absence of resistance was equally important. It allowed the pair to transpose or depart from regular procedure without reflection.

Learners, like the pair in our study, are expected to shape their own learning activities in ways that fit with their personal abilities, knowledge, and needs. They have to plan their own project, decide how to move from A to B, when to do what, and where to do it. To cater these pedagogies designers are challenged to develop instructional strategies that prevent learners from being unnecessarily restricted. The current breed of technical artifacts, and the scenarios that accompany them, show increased flexibility. Still, there is an inherent tension: too much rigidity may downplay creative agency, but too much flexibility may not result in a productive learning trajectory. Our study suggests that 'soft' constraints are an important resource in this

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problem. When carefully tailored, they may help learners to uncover a space of alternative action in taken-for-granted activity.

Appendix 1: 'The kitchen project' syllabus (fragment)

The project syllabus contains three chapters, each corresponding with a specific domain. Chapter 1 contains communication assignments. These are about language (i.e. native Dutch, German and French) and the practical use of language. Chapter 2 contains technology assignments. Math, physics and chemistry are relevant knowledge domains here. Chapter 3 contains civics assignments: about government, society and rules and regulations. Below, one finds the technology and communication assignments (translated from Dutch) as they are presented in the project syllabus. The assignments are accompanied with several examples (e.g. of technical drawings and invoices) and other background information that is necessary to complete them. This information is not presented here.

Technology assignments

Situation
The Ten Donker family has been using their kitchen for three years now. They would like to have a new one.
New equipment: microwave, dishwasher, hood and sink with tap.
Other (existing) equipment is taken up in the new design.
How to go from A to B?

Attention points (math, physics, chemistry)
Making and reading of a technical drawing
Recognizing and applying technical symbols
Calculation of costs (tender/VAT en discount percentage)
Working with formulae (U = I*R and P + U*I) and derivatives
Functioning of meter cabinet
Analogy water pressure and water usage
Electric power and cost calculation
Further deepening: replacement resistance/resistance metal wire

With this assignment you will have to translate the wishes of the client to technical solutions:

"Sunday breakfast comes with fresh orange juice"
The Ten Donker family has an electric orange-presser. Where have you planned the socket?
"Why should a refrigerator use more energy than necessary, it's expensive and bad for the environment"
What should the family pay attention to, according to you?
"We like clean walls with no cables and our cooker in the middle"
Where do you place the gas- water- and light conductors?

Communication assignments

Description
The Ten Donker family wants to have a new kitchen installed in their home. They have taken over an old kitchen with the acquisition of their house three years ago. They plan to outsource the work to a licensed firm. They have been told by friends that German (French) firms are particularly good in kitchen installations.

Write an email to a German (French) kitchen firm in which you kindly request a brochure
Write an email on behalf of Kuchenland, Nordhorn (Pays des cuisines, Lille) in which you make an appointment with the Ten Donker family to do measurements
Kuchenland (Pays des cuisines) also invites them to visit their showroom in Nordhorn (Lille)
Kuchenland (Pays des cuisines) sends the family a tender

Relevant competencies
For this assignment you will have to:
Write a brief letter in German or French
Make a proper invoice in Dutch
Write a reflection on the collaboration and functioning of the partners (in Dutch)

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Appendix 2: Plan for the 'flower project' by Lucas and Oscar

	Time	Done (check)
Communication		
1. Plan	30 min	
2. look up export law and regulation	30 min	
3. business letter in Dutch	20 min	
4. 10 questions about civilians	15 min	
5. Report of civilians	30 min	
6. flying flowers:		
Summarize activities	40 min	
Make brochure	50 min	
7. Do 5 questions with German text	30 min	
8. Make reflection	20 min	
Technology		
1. Intake with customer about wishes for truck	30 min	
2.make autocad drawing	3,5 h	
3. discuss drawing with client	30 min	
Civics		
Paper:		
1. Think of topic and questions	30 min	
2. Gather information	50 min	
3. Write paper	2 h	

Appendix 3: Excerpts from the protocol (L = Lucas, O = Oscar)

Episode 1

Line	Time		Action
97	16.06	O	Adds 'task' card under Day 1
98	16.12	O	Labels 'task' card 'Communication'
99	16.14	O	Adds 'task' card under Day 1
100	16.20	O	Labels 'task' card 'Project plan in workspace'
101	16.24	L	Put everything underneath communication?
102	16.27	O	Yes, under communication, if I do this one, then you can do the next.
103	16.32	L	Project plan, what's that a part of, communication, right?
104	16.38	O	We already have an project plan, right?
105	16.55	O	Adds links between cards (Fig. 3)
106	17.01	L	Oh, you do it like that..OK

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Episode 2

129	25.01	L	Adds 'task' card under Day 2
130	25.03	L	Labels 'task' card 'Communication'
131	25.05	L	Adds 'task' card under Day 2
132	25.09	L	Labels 'task' card 'Mail for brochure'
133	25.13	O	Adds 'task' card under Day 1
134	25.17	O	Labels 'task' card 'Design kitchen'
135	25.21	L	Adds 'task' card under Day 2
136	25.25	L	Labels 'task' card 'Tender'
137	25.27	L	Adds links between cards (Fig. 4)
138	25.28	O	Edits comment window of 'task' card

Episode 3

141	25.34	L	What's kitchen design a part of?
142	25.36	O	That's part of technology.
143	25.38	L	Then we should perhaps leave communication out.
144	25:41	L	But do only the things that we need to do on that day.

Episode 4

154	28.24	L	Adds 'time' card
155	28.26	L	Labels 'time' card 'Total time = 150 min'
156	28.27	O	Where do we put technology?
157	28.29	L	I'm not sure..
158	28.34	O	Adds 'task' card
159	28.37	O	Labels 'task' card 'Technics'
160	28.40	O	Let's do here, I've put 'technics' instead of technology.
161	28.41	L	Adds link between cards
162	28.43	O	Deletes 'Technics' card
163	28.45	O	Edits 'Design kitchen' card
164	28.48	O	Adds label '(technical drawing)'
165	28:52	O	But, we are now, eh.. per part..
166	28.54	O	Moves 'Design kitchen' card to third column
167	28.57	L	Moves 'Design kitchen' card back to first column
168	28.59	L	Adds 'task' card
169	29.61	L	Labels 'task' card 'Technology' (Fig. 5)
170	29.62	T	So we'll also get communication

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Episode 5

242	38.55	O	I would like to continue with technical drawing.
243	39.08	L	What's that a part of?
244	39.14	L	Is that part of communication, or not?
245	39.15	O	Yeah, well, it's not necessarily communication, but I think it belongs there…
246	39.20	L	Shouldn't we just remove communication?
247	39.25	O	No, we'll just do planning for a day, not for a course, we'll just…shall we do that?
248	39.28	L	Shall we then remove communication and stuff?
249	39.34	O	I think we'll just have to plan what we do on that day.
250	39:37	O	And then we put above there what it is, Eyh?
251	39.38	L	Ok
252	39.40	L	Like I've put 'technology' above it.
253	39.43	O	Yeah, like that.

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