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Evaluation/Modification Cycles in Junior High Students' Technological Problem Solving

DAVID MIODUSER & DOV KIPPERMAN

Tel-Aviv University, School of Education, Ramat-Aviv, Tel-Aviv, 69978, Israel
(E-mail: miodu@post.tau.ac.il)

ABSTRACT: Technological problem-solving knowledge and skills have become primary components of almost any curricular endeavor in technology education for the last decades. However, our understanding of the way students approach such tasks and generate solutions is still incomplete. The main goal of this study was to trace closely Grade 7 students' work while engaged in design tasks within an unstructured learning environment. We report on a specific fragment of the process, namely on the *evaluation/modification cycles* which the students went through after completing the construction of the first version of a solution. The study focused on: (a) identifying the conceptual constituents of these cycles; (b) the students' decisions with reference to the original design goals in the course of these cycles; and (c) the formulation of a general reflection/decision/action model characterizing these cycles.

Keywords:

INTRODUCTION

Technological problem solving, as performed by both experts and novices, has been a subject of study for several years (e.g., Buciarelli 1996; Vincenti 1990). The generation process of technological solutions may take a variety of forms: from a completely open-ended process (e.g., no *a priori* plan exists to guide the solution process), to a highly structured ones (e.g., strictly following the course of action commonly mentioned in the literature as "the design process"). In all cases, problem-solving implies a wide range of cognitive and metacognitive processes, e.g., invention, exploration, experimentation, reflection-in-action (Pacey 1999; Rowe 1987; Waks 2001). It can be characterized as a highly creative and multi-faceted course of action in which informed doing-and-evaluation loops gradually advance the generation of the solution. Reflection, evaluation and knowledgeable decision making appear to be essential components of this process.

Technological problem solving knowledge and skills have also become primary components of almost any curricular endeavor in technology education for several decades (e.g., DES 1990; Nuffield Design and Technology 1995; Science & Technology for the Junior High School 1998). However, in contrast with the malleable and many-sided process depicted in the research describing real-life problem solving, most curricular translations of the nature and character of this process have resulted in overly structured and rigid didactic models (Hill 1998; Mioduser 1998). These models are mostly linear and comprise a variable number of stages, all having in common at least four steps: problem identification, exploration of alternative solutions, realization of the chosen solution and its evaluation (e.g., Hutchinson & Karsnitz 1994; Johnsey 1995). In some cases, feedback paths among stages are suggested. However, due to implementation constraints (e.g., time, logistics, clarity of teaching goals, teachers' linear perception of the process), these cyclical models rarely transcend the textbooks to be activated in the classroom. Contrasting with the researchers' description of the inspired nature of technological problem solving, little room is left in its curricular counterpart for reflection, formative evaluation and resourceful decision making beyond the detailed guidelines prescribed in a range of teaching materials. Moreover, most curricular solutions seem to ignore current pedagogical approaches towards technology education which encourage (individual and group) student-controlled knowledge-construction processes within unstructured and resourceful learning environments (Hennessy & Murphy 1999; Hill 1998; Fleer 2000; Resnick & Ocko 1991). This gap between the highly creative and flexible nature of the design process of technological solutions as characterized in the research literature, and the highly structured and prescriptive models of this process as incorporated in teaching materials, represents a crucial source of learning and motivation difficulties in design-based activities (Baynes 1992; Hill & Anning 2001; de Vries 1996).

Recent research results indicate that students' problem solving resembles the way expert designers' or technology practitioners' approach the solution process, in particular in open-ended tasks (Hill & Anning 2001). Students follow a variety of solution paths (e.g. they may begin with exploration of materials then building, or begin building then evaluating the design and reworking it, or begin planning and drawing then building and evaluating the results) and approach in different ways the lack of correspondence between expected and actual results (Fleer 2000). While developing a technological solution, students seem also to engage in a constant reformulation of intermediate goals at different levels (from macro to micro) (Fleer 2001). A great deal of tacit knowledge, which can be observed in students' actions but cannot be easily verbalized or formalized by them, seems to develop during the process (Kipperman 1998). In addition, the whole process, rather than being linear and ordered, appears to be iterative and cyclical with 'evaluation' being a driving factor for the creation (or ending) of design phases.

Notwithstanding the accumulating research results, our understanding of the way students approach technological problem-solving tasks and generate design solutions is still incomplete. Essential questions still to be addressed include, whether the conceptual framework and models used to characterize expert designers' problem solving can be used directly to understand the students' performance in design tasks; whether particular models should be developed to identify and interpret students' design activities within *unstructured* learning tasks; and what characterizes students' reflection, decision-making, and doing cycles while 'debugging' a faulty technological solution.

In light of the centrality of the generation of technological solutions in technology education on the one hand, and on the other hand the need to increase our understanding of students' design thinking and doing of these solutions, we conducted the study reported here. Its main goal was to trace closely Grade 7 students' work while engaged in design tasks within an unstructured learning environment. We report on a specific fragment of the process, namely on the evaluation/modification cycles the students went through *after completing the their first version* of a solution (e.g., a device). In open-ended and unstructured tasks, this phase of the solution design process is of particular importance. In previous phases the students defined their design goal, and their main motivation was to produce a working solution in the shortest possible time. But the solution does not always work, or if it does, it may only partially fulfill the original design goals. Then comes the time for diagnosis, reflection, decision-making and action aiming to close the gap between expected and observed functioning of the solution. This phase usually takes the form of a rich and cognitively demanding cyclical process. On it, we focus this present study, addressing the following questions.

1. What are the constituent units of the evaluation-modification cycles carried out by the students in a technological problem solving task?
2. How do the students relate to the original design goals within these evaluation-modification cycles?
3. How can these evaluation-modification cycles be characterized in a general reflection/decision/action model?

METHOD

The participants in the study were five 7th grade students from a regional school in the north of Israel. This group was randomly selected out of six groups enrolled in an annual technology course. The study was conducted during the second semester, when the students were engaged in building three-dimensional working models using Lego kits – and additional materials according to construction needs. The classroom setting included construction kits, computers, and a variety of materials, resources and tools.

The main tutor for the cause was an experienced teacher with a strong technological background. He was assisted by another teacher with a similar background. Their pedagogical practice, by their own report, was grounded on the constructivist approach. For the model construction task, the only direction given was the overall definition of the task accompanied by a range of minimal requirements (e.g., to build a *working* device). From then on each student proceeded along her/his own learning/working path, assisted – when needed *and* requested – by one of the teachers. Occasionally, in response to emerging issues, the teachers initiated subgroup or whole-group discussions.

The study was conducted during 12 two-hour sessions. Participants were encouraged to think out loud during the sessions. An observer (the second author) audio-recorded the sessions, focusing on the five students' descriptions and interactions, and recorded observations of the students' actions. In addition, interviews were conducted during the sessions to obtain students' explicit reflections on particular issues (e.g., a building decision, a 'debugging' action).

Given the study's goals, population, nature of the learning setting, and pedagogical philosophy of the teachers, mainly qualitative methods were adopted for the collection and the interpretation of the data. All recorded and observed data were transcribed. The reliability of the transcriptions was evaluated by the two teachers, and identified discrepancies were discussed and settled. The transcribed data were analyzed in a number of stages: (a) segmentation of the raw data into action and speech units; (b) identification of meaningful segments or phases in the working process; (c) distillation of variables and sub-variables out of the action and speech units; (d) gradual construction of a model – the evaluation/modification space- emerging from the configuration of the variables; and (e) identification of individual paths (for each student) within the evaluation/modification space model.

RESULTS

The results will be presented in the order of the research questions given above and will follow the chronological account of the data analysis process.

> Research question 1: What are the constituent units of the evaluation-modification cycles carried out by the students in a technological problem solving task?

Identification of significant action and speech units

The aim of first stage of the analysis of the collected data was to identify and characterize the units (of thought, of action) out of which evaluation-modification cycles are built. According to Guba and Lincoln (1985), these units are "best understood as single pieces of information that stand by themselves, that is, are interpretable in the absence of any additional information"(p. 203). All transcripts were segmented into "action units" (e.g., looking at the kits' manual, building [a part of the] the car, connecting the device to a power supply) and "speech units" (e.g., "I want the manual", "I am going to build a tractor", "I want it to move slowly", "I am going to do some modifications", "Why doesn't it work?").

Next, three phases (or aggregates of units) were identified in the problem solving process: solution construction, evaluation and modification. The *construction* phase included the planning and construction of the device, ending just before the student tested it to see if it worked (e.g., connected it to a power supply). The *evaluation* phase starts with the functional testing of the device, followed by *modification* actions according to the evaluation results.

We observed that the last two phases recurred cyclically and became intertwined, until the student eventually decided that the task has been completed. This cyclical construct is the section of the learning process on which we focus here.

Samples of speech and action units in the evaluation and modification phases are provided in Table I. Implicit in the table is also the cyclical aspect of this phase, as depicted in Figure 1.

TABLE I
Sample of speech and action units in the evaluation and modification phases

Phase: Evaluation		Phase: Modification	
Speech units	Action units	Speech units	Action units
	Connecting – it works		
S: "how come it moves so slow?" : "try it on the floor" **S**: "it's obvious that it will move on the floor"			
			Trying on the floor – works but turns
S: "I know why, this turns to one side, and this to the other"			
			Changes polarity of wires
	Connects – it works		
			Changes polarity
	Connects – it works		
S: "now it goes to the same direction. It's time to deal with brakes and other things"			

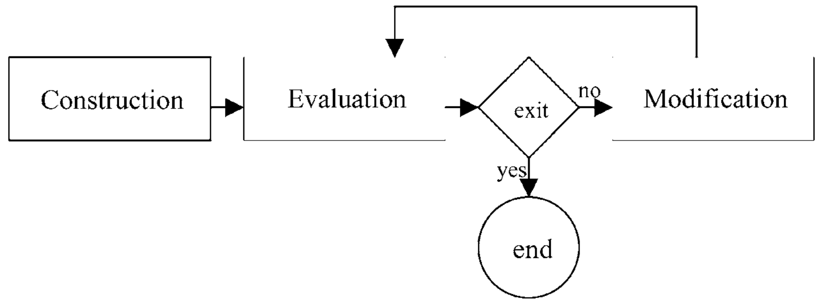

Figure 1. Evaluation-modification loops.

Indicators for the analysis of students' performance

The "speech units" and the "action units" at each phase were analyzed and grouped to conform to a code set. Glaser and Straus (1967) advocated an inductive approach to the development of a code set. Grounded theory states that codes should be "grounded", that is, derived from the data. Straus (1987) calls the process "open coding", defining it as the unrestricted coding of the data aimed at providing concepts that seem to fit the data. Tesch (1990) refers to "empirical indicators", that is, actions, event and words which may be used to develop codes. An example of this study's speech and action units, their grouping under indicators, and the assigned codes is shown in Table II. The complete coding set for the evaluation and modification phases is presented in Table III.

Indicators pertaining to the *evaluation phase* reveal an interesting variety of positions adopted by the students after concluding the first version of

TABLE II
Sample of codes for speech and action units

Phase	Speech or action units	Indicator	Code
Evaluation	Connecting – it works	Functioning test	[E1]
	"I don't understand why it isn't working"	Diagnosis	[E2]
	"How come it moves so slow?"	Valuation	[E3]
	"Enough with this model"	Abandon goal	[E51]
	"I want it to go faster"	Improve goal	[E54]
	"I need electricity here"	Plan action	[E6]
Modification	Replacing a small wheel with a big wheel	Repair	[M2]
	Changing the wire's polarity	Troubleshoot	[M3]
	Adding a motor	Make changes	[M4]
	Changing the track slope	Make experiment	[M5]

TABLE III
Coding set for the evaluation and modification phases

	Code	Indicators
Evaluation phase	[E1]	**Functioning-test** (e.g., connecting the model to a energy source to check motors functioning)
	[E2]	**Diagnosis** (e.g., systematic checking of connections and polarity)
	[E3]	**Valuation** (e.g., assessing actual velocity level and setting desired level)
	[E4]	**Exit decision** (e.g., the result is satisfying and the task is considered done)
	[E5]	**Reference to goal** [E51] Abandon goal (and set new goal) [E52] Reduce goal (compromise between expected and realized) [E53] Stick to goal (correct result towards goal attainment) [E54] Improve goal (upgrade original plan)
	[E6]	**Action-plan** (e.g., replace small wheels by large wheels intending to affect velocity)
Modification phase	[M1]	**Constructing a new device** (e.g., disassembling faulty model and building a different one)
	[M2]	**Troubleshooting** (e.g., change polarity of connections)
	[M3]	**Repairing** (e.g., reconnect loose or unattached transmission components)
	[M4]	**Making changes** (e.g., lessen number of structural parts to reduce weight)
	[M5]	**Making experiments** (e.g., change testing environment to check functioning in varied conditions)

the device, i.e., devising ways to test its functioning, evaluating its current state against the original design goals, making decisions regarding the extent to which they adhere to the original goals, and planning improvements.

The "functioning-test" indicator refers to the initial steps taken by the students to probe the device's functioning, e.g., connecting it (motors, lights) to a power source.

The "diagnosis" indicator encompasses a wide range of actions that aim to explore and isolate the causes of a device's malfunctioning, e.g., polarity checking, ordered examination of the functioning of each connected component, exploration of friction levels in transmission components.

If, as a result of the functioning-test, the device appeared to work at a reasonable level, "valuation" actions were executed by the students. These are attempts to attribute qualitative or quantitative values to different aspects of the device's functioning, in order to make decisions about the continuation of the work. Examples of valuation units were: "(The car's) front rises, it needs more weight in its front"; "It's weak, one of the motors does not function"; "Mine is slow but strong"; "The more I press the more air flows".

The "reference to goal" indicator encompasses a variety of stances towards the original goals of the task in the light of the actual results: to stick to the (still unattained) goal (e.g., "I still need a connection between the axes here"); to expand and improve it (e.g., "I'm going to make it faster"); to compromise and reduce it (e.g., "It was supposed to be a ironing machine...but since it did not succeed ironing, it will be now a filing machine") ; or even to abandon it and set a new goal.

The "action-plan" indicator relates to the definition of actions to be implemented on the device, following the evaluation.

The indicators in the modification phase represent categories of actions which are in correspondence with the decisions made in the evaluation phase. The students may make changes to improve functioning (e.g., lessen number of building components to reduce weight), experiment with variations of the solution (e.g., run the car on different surfaces with varied textures), or dismantle the device and start a new one.

Summarizing, the product obtained at this stage of the data analysis was a structural or static inventory of actions related to the solution generation process, as presented in Table III. Or, referring to our first research question, the defined indicators represent the set of constituents of the students' evaluation-modification cycles while creating a technological solution.

Research question 2: How do the students relate to the design goals within the evaluation-modification cycles?

During the *evaluation phase*, students focus on testing the artifact and on planning subsequent actions according to the test results. When the test results are positive (the device works, even if not as expected), the findings indicate that student regard the goals as "achieved" or "partially achieved" (e.g., "It turns but slowly", "It goes backwards but forwards it is stuck"). This usually leads to the decision to *improve* or *expand* the original goal to enhance the performance of the device (e.g., "I will improve it", "I will increase its power").

When the device does not work, this may lead to more radical modifications in the original goals, to their *replacement* or even *abandonment* (e.g., "I give up with this work", "I will make an helicopter instead [of a car]").

In the *modification phase*, the actions actually taken also reveal different attitudes towards the original design goal. For example, Table IV presents an excerpt of one student's sequence of actions, and the corresponding fluctuations in regard to the original design goals.

As shown in this Table, attempts to test the solution under a variety of conditions, or to add missing components (pursuing the expected functioning), respond to the students' adherence to the original goal. In contrast, disassembling the device and starting a new construction path reflect a change (and even abandonment) of the original goal.

TABLE IV
Reference to design goals in one student's modification-actions sequence

Test	Action	Modification category	Reference to design goal
It works	Adds motor	Improvement	Improve goal
It works	Tryout in slope	Experiment	Stick to goal
It does not work	Examine mechanism	Diagnose	Stick to goal
It works	Put on floor	Experiment	Improve goal
	[section omitted]		
It does not work	Attach front transmission	Diagnose	Stick to goal
It works	Add transmission in the back	Diagnose	Stick to goal
It does not work	"I take it apart, maybe the motor does not work"	New device	Change goal

Applying the same analysis scheme to all data collected resulted in four main attitudes towards the original design goals, namely: sticking to, improving, modifying, or changing the goals.

Sticking to the original design goal (e.g., change wiring; try device on different surfaces) was usually associated with diagnosis-related actions. When discrepancies appeared between the expected and actual functioning of the device, students who stuck to the original goals entered a series of action loops comprising diagnosis (and formulation of hypotheses), repair, and evaluation. After a number of evaluation/modification cycles, if the problem still persisted, most students chose to change the design goals and build a new device.

Improvement of the design goals (e.g., "It should go faster"; "I will replace the wheels") usually occurred when the initially designed device worked at a reasonable level, even if not as expected. The improvements took the form of the addition or replacement of parts to enhance a given function or to expand the original functions.

Modification of the goal usually implied an element of compromise of the original design goals, due to difficulties in realizing them in the device. Modification of the goal usually came after several cycles of perseverance with the original goal did not produce the expected results.

Changing the design goals (e.g., from a car to a conveyor belt; from a carousel to a washing machine), was a drastic decision, usually followed several evaluation/modification cycles when the student felt that the project had come to a dead end. This situation was often associated with a feeling of not really knowing what went wrong with the device, of what was causing the malfunction.

One additional remark must be made regarding the dynamic aspect of the work process. Students' work was never characterized uniquely and consistently by one single approach toward the design goal. In addition, students never followed a simple linear path, namely, [a-decision-regarding-the-goal] >> [completion of the project]. On the contrary, in all cases the different approaches were used in various combinations during several evaluation/modification cycles (up to 15 cycles in the case of one student, a mean of 6–8 cycles for most other participants), until the devised solution satisfied the posed requirements.

Research question 3: How can evaluation-modification cycles be characterized in a general reflection/decision/action model?

Here we elaborate on the dynamic aspect of the process performed by students, or the way different configurations and sequences of constituents appeared in the course of the students' work. This analysis allows us to construct an action space within which individual paths or cycles can be identified.

Figure 2 offers a graphic representation of this action-space, which we call the evaluation/modification space model.

We found that all the students, after the completion of the first version of the device, performed functioning-testing activities (e.g., connection to a power source or computer-interface box). Depending on the results of the test, the students opted for one of two different paths: if the device did not function above an expected level, they started a series of diagnostic probes to reveal the causes of the limited function; if the device did work at a reasonable level, they initiated valuation activities aimed to qualify aspects of its functioning (e.g., Has it got enough "force" to climb the hill?).

Following these activities, and regardless of which of the two above paths they had chosen, the students considered whether to abandon the process ("It does not work anyway", or "It works fine, it's done") or not. If they continued, their next decision related to the extent to which they decided to adhere to the original design goals by one of four main approaches (as mentioned above in relation to research question two). The evaluation phase ended usually with an action plan for the modification or improvement of the device, initiating a new loop in the cycle.

The modification phase consisted in the actual implementation of the planned actions. Once the planned work was done, a decision was made whether to finish the project or to undertake an additional evaluation of the changes. In this way, the project proceeded through evaluation-modification loops until the student decided to end it.

This evaluation/modification-space represents a powerful tool both for research and teaching purposes. On the one hand, it allows the reconsideration of the protocols of students' speech and action units, allowing us to trace the design path followed by the students while constructing the solution. On the other, it also allows us to model any individual students' working process both in quantitative (e.g., number of units, number of cycles) and qualitative (e.g., reference to goal, consistency) terms, informing assessment and pedagogical decision making.

DISCUSSION

The research literature regarding the conceptualization and implementation of technological problem-solving processes by experts and novices – reveals a substantial disparity between theoretical and empirical models of these processes. Theoretical models describe (and prescribe) what designers ought to do, proposing a clearly structured and sequential process. Empirical models deal with what designers actually do, and this turns out

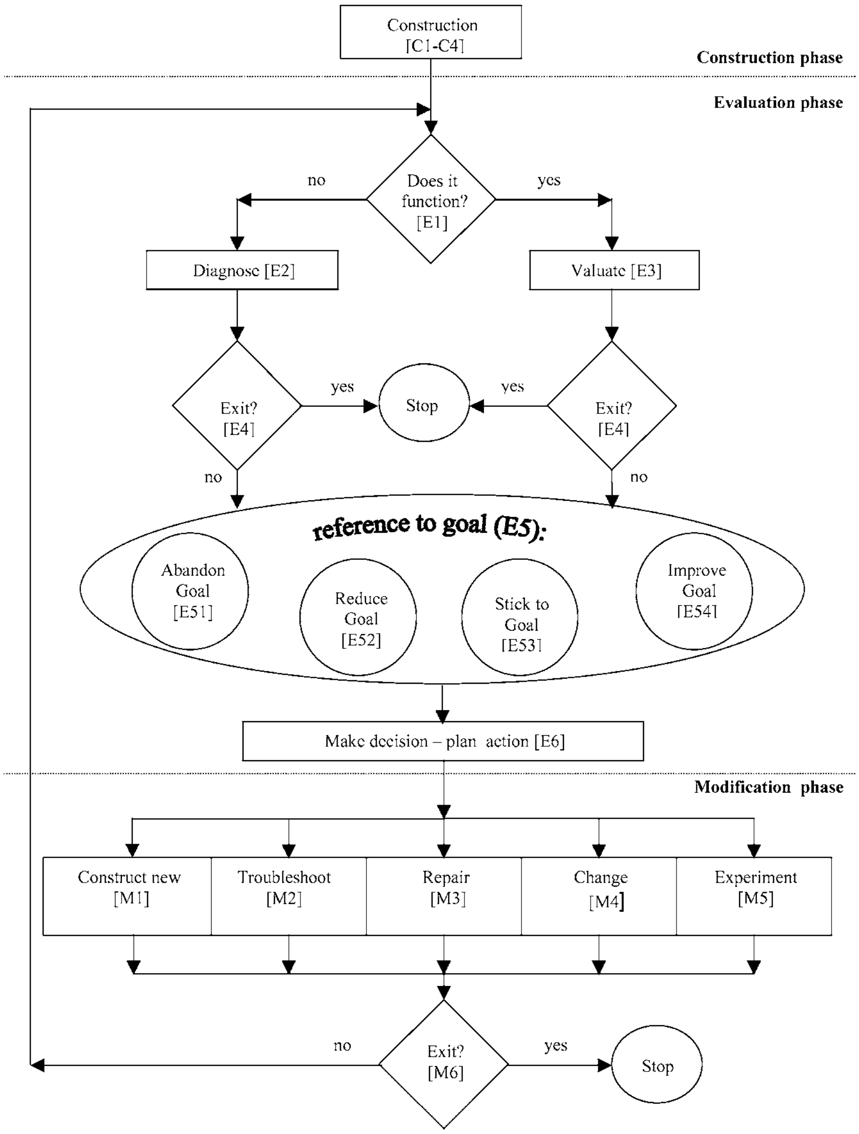

Figure 2. Evaluation/modification space.

to be a highly malleable, cyclical, and knowledge-rich process (Gero & Mc Neill 1997; Norman 1998; Owen 1998). This disparity is also mirrored in the educational instantiations of design activities, in the form of a clear incongruity between curricular aims (what students are expected to do) and their classroom materialization (what students actually do). While most curricular materials propose (as a didactic translation of the formally defined models) a teaching sequence based on design stages (DES 1990; Hutchinson & Karsnitz 1994), classroom observations show that students do not design/learn in such a structured and linear fashion (Hennesy & McCormick 1994; Hill & Anning 2001).

The study reported in this paper represented an attempt to characterize the actual strategies, working paths, cognitive and metacognitive operations carried out by a small group of 7th graders while solving a technological problem in an unstructured learning environment. More specifically, we have focused on a particular fragment of the process which: (a) is highly dense in cognitive and metacognitive performance, and (b) becomes a space for multiple cycles and loops in the search for a desired/acceptable solution to the problem. This phase has it beginnings immediately after the first version of the solution has been generated, and it ends when the student decides that the project has been completed. We defined this fragment in the problem solving process as the *evaluation-modification* phase. In the following, we will elaborate on several issues emerging from the data collected.

The initial set of issues relates to our first research question, namely, the identification of the constituents of the evaluation-modification cycles. First, the indicators shown in Table III represent categories or classes of action taken by the students in the course of the design process. In more general terms, these can be considered within the context of the "technological primitives" model for describing the cognitive architecture of technological problem solving presented in a previous paper (Mioduser 1998). In this model, four layers of "primitives" or conceptual building blocks – namely rudiments, methods, mental models and metacognitive primitives – comprise the intellectual-toolbox serving technological problem solving. *Rudiments* are the basic building blocks of technology related performance. These consist of a wide range of knowledge units which are activated in different situations, e.g., for operating devices, using tools, building models, or programming a computer. The problem-solver's *mental model* of a target system or a problem situation is a key factor in the problem solving process, whether the person is trying to understand a system, predict its behavior, operate it, repair it, or design a new one. *Methodological primitives* are the procedures involved in solving technological problems. Some relevant instances of these primitives, alongside (any version of) the design process, are information retrieval, model building, troubleshooting, or 'debugging' methods. Finally, *meta-level primitives* concern the ways the learner uses primitives from the previous levels (e.g., rudiments, models, methods) and controls the problem-solving process. They may be referred to as the metacognitive aspects of the technological problem solving process.

Within this framework, the set of indicators we have defined are primitives pertaining to the methodological and metacognitive layers, while the particular actions within each indicator (e.g., change polarity, add a transmission compound) are primitives pertaining to the technological rudiments layer. The technological primitives model was conceived as conceptual tool for mapping technological problem solving skills, and as more research is completed (as in this study), we are able to map more instances of primitives and place more content within the cells of the conceptual skeleton.

The next set of issues concerns our second research question, students' reference to the original design goals. We observed that during countless loops and cycles, every evaluation or modification action also represented (some times implicitly, other times explicitly) a constant scrutiny of the extent to which the original goal has been achieved. In addition, each student defined a sort of (conceptual) threshold which acted as a divide between two differential attitudes towards the results (and hence towards the design goals): (a) satisfaction with the result so far achieved (even if it is a partial result) leading to an adherence to the goal, and even to the decision to expand or improve it; or (b) dissatisfaction with the result so far achieved leading (for a limited number of trials) to attempts to achieve the original goal, and if these attempts did not lift the results above the threshold, to the reduction and even replacement of the original goals.

The importance of the results of the microanalysis is that they reveal the complexity of the students' analytic and synthetic stances towards the creation process of the technological solution. Given the appropriate context (namely an unstructured task, enough time, and no obligation to follow any predetermined path), students develop a complex model of the interrelationships between pursued goals and intermediate results. One important cognitive resource evolving in this process are weighing or valuation abilities, by which students define the variables they use for making decisions. Another equally important evolving resource is the ability to generate useful criteria (concerning the relevant variables), to make decisions regarding the continuation of the work. In more general terms, these resources can be seen as necessary constituents for the development of more complex problem solving aptitudes, such as the ability to carry out cost-effectiveness-analysis and informed-goal-oriented processes.

Our third question referred to the formulation of an overall model or mapping space of the evaluation/modification cycles fragment of the design process. Our observations in this study reinforce claims on the cyclical character of the design process (e.g., Bucciarelli 1996; Hill 1998). As already mentioned, most prescriptive models depict the design process as sequence of stages each of which focuses on a particular goal, e.g., definition of the problem, or evaluation. Mioduser (1998) suggests a different formulation of the design process in functional (rather than sequential) terms. By this approach, students are engaged in performing four main functions, which appear in a cyclical and recurrent manner during the process of devising a technological solution. These functions are (a) *identification and definition* (e.g., of the problem, of alternative solutions); (b) *exploration* (e.g., of constraints for the solution, of users' requirements, of ideas, materials, energy forms, information forms, mechanisms or processes); (c) *implementation* (e.g., of probes for alternative materials; of the chosen solution) and (d) *evaluation* (at every step and phase as needed). All four functions are interconnected and may appear at any given phase along the solution generation process.

The micro-analysis of the students' speech and action units showed particular instantiations of these functions (e.g., 'exploration' took the form of 'diagnosis' or 'experimentation' activities), as well as particular configurations of these instances, composing the evaluation-modification cycles. In addition, the reconstruction of individual students' solution-generation path with the help of the model clearly showed the complex cyclical character of the problem-solving process.

Concluding remarks

This study was conducted in an unstructured learning milieu, allowing us to examine students' spontaneous strategies and performance. We had the opportunity to track students' own re-formulation of the problem-solving phases sequence, and of the design-tasks sequence within each phase, guided by their perceived requirements and needs. In practical terms, the model generated from the collected data offers a comprehensive account of, and organizing structure for, the students' decision and action-making space. This tool may have important implications for students, teachers, and curriculum developers, concerning design-based learning tasks.

The model offers students an external mapping tool for guiding their reflection on their own working process (e.g., as regards to evaluation-loops, definition of goal-satisfaction-threshold, consideration of alternative lines of action). It also offers teachers a tool for the re-definition of different aspects of the instruction, e.g., for defining their role in coaching the students' design cycles, or for devising assessment concerning the students' execution of the different design functions. Finally, the model supplies curriculum developers with a framework for designing learning tasks which are related to real life problem-solving processes as performed by the students (Hill & Anning 2001), for creating materials based on didactic solutions other than structured and sequential design learning-tasks (Norman, 1988), with an emphasis on design functions and technological-primitives categories rather than on prescribed design scripts.

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