PEDAGOGICAL BACKGROUND FOR TECHNOLOGY EDUCATION - MEANINGFUL LEARNING IN THEORY AND PRACTICE

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ABSTRACT

One important theme in technology education is the growing need to develop the type of pedagogies that encourage pupils in authentic and meaningful learning experiences. Often, the teaching strategies of technology education are only a matter of teaching the handling of materials and tools, and the production of mere objects does not consider how to incorporate broader pedagogical connections in comprehensive school technology education.

The concept of meaningful learning has been brought into use in technology education of comprehensive school because some generic skills should also be learned in the work process. In this article, learning in technology education is approached from the point of view of meaningful learning. In addition, the realization of practicing the meaningful learning in the teaching of technology is examined.

Keywords: Meaningful Learning, Pedagogies, Technology Education.

INTRODUCTION

The development of technology has been especially rapid in the last twenty years. Changes in the economy, nature, production and society together with increasing scientific and technological knowledge have made it necessary to transform school teaching in the field of technology education. Materials, machines and techniques in technology education have developed rapidly, but the pedagogic contents are regrettably restricted often to only the product to be made.

The question of whether the product or the process is more important in the teaching of technology has arisen and will arise more and more often. Unfortunately, often the products of technology are perceived as being more important than thinking and learning. However, the artifact itself, although well made, should never be the goal in itself, but every lesson of technology education should offer students useful capital even in the broad senses of forming a positive realistic worldview and strengthening self-concept.

In Europe, one important theme is the growing need to develop the type of pedagogies that encourage the active involvement of pupils in authentic and meaningful learning experiences within craft and technology (Dow, 2006). The same conclusion is supported by Suojanen (1993) and Rowell (2004), according to which the production of mere artifacts does not take wider connections to the technology education programs of comprehensive school into account. Peltonen (1988), Weston (1990) and Williams & Williams (1997) also point out that the teaching strategies of technology education are too often only a matter of teaching the handling of materials and tools. In spite of some good efforts, the legacy of behaviorist, teacher centered, whole class teaching methodologies, with teacher as expert and student as passive recipient of knowledge, appears to continue to assert itself as the dominant orthodoxy in education still today (Dakers, 2005).

Furthermore, studies on children's technological work have tended to show that students usually build only one structure or device, with the emphasis falling on actual construction, rather than on other aspects of the activity, such as design (Cajas, 2001; Schauble et al., 1991). Generic processes such as investigating, planning, modeling, making and evaluating should be incorporated into task sequences for students more often (Rowell, 2004).

1. Subject matter and meaningful learning

The concept of subject matter has been implemented into comprehensive school technology education because certain generic skills should also be learned in the process of working. The early model of subject matter includes motivation, planning, working and evaluation. Its aim is to introduce alternatives to object thinking and lead students away from merely copying the process of the work. Subject matter learning was introduced in the early 1970s and was further developed in the 1980s. These models have later been examined by Suojanen (1991; 1993) and Autio (1997; 2005).

According to Suojanen (1991), the significance with which knowledge and skills are developed and the importance of the whole working process is emphasized in subject matter learning. In subject matter working it is possible to take factors into consideration, which are related to the environment of the work. For example, the subject matter developed by Suojanen (1993) is based on the theoretical model of the planning process and manufacturing process of the product, as presented in Anttila (1993). The model puts a strong emphasis on the planning of the product and the manufacturing process. Evaluation is also strongly emphasized and accompanies the subject matter throughout the entire process.

The idea of meaningful learning (Engeström, 1981; 1990) gives the subject matter a clearer theoretical engagement, which has been developed from the theory of the adopting of mental acts (Galperin, 1972; 1979) and the theory of developing the operations of theoretical thinking (Davydov, 1977; 1982).

In the larger context, subject matter and meaningful learning has several similarities to project-based learning, which also has the potential to enable pupils to research, plan, design and reflect on the creation of technological projects (Doppelt 2005). Moreover, they are close to the activity categories design, make, utilize and assess as introduced by Weber & Custer (2005). Related literature is also available on effective pedagogy for technology education (Anning, 1997; Hill, 1998; Hill & Smith, 2005; Parkinson, 2001; Williams, 2000).

2. The idea of the meaningful learning

Every situation in everyday life contains much more information than a human being is able to receive effectively and is able to store into his memory; thus learning often simply is receiving information and storing it mechanically. It is especially difficult to remember loose functions and subject catalogues because the human being usually focuses his mental resources towards what is essential to his own life, work and hobbies. However, the human being needs the material to be learned to be sensible and significant to his own life. The information must be functional and useful in real assignments and situations. This is the starting point for meaningful learning. One can find the model of meaningful learning as presented in Figure 1.

2.1. Motivation process

Meaningful learning begins from practical real life problems and conflicts. When a human being notices that his information and his skills are insufficient to perform a task or to handle a situation, an internal conflict is created. If a human being is able to perceive this conflict as an interesting and educational challenge, meaningful learning can begin. After this, the learning aims to solve the problem and independently control the matter. The human being is no longer a mere vessel for storing information that has been processed, but rather a researcher trying to solve a problem.

Both the subject matter and meaningful learning begin from motivation. However, the essential difference is the fact that in the simplified model of subject matter,

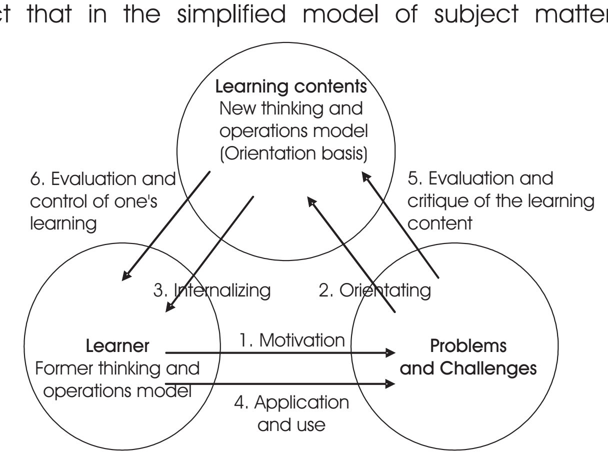

Figure 1. The idea of meaningful learning (Engeström, 1981)

motivation has only a few deeper connections and is usually based on various stimuli binding to external factors by the product to be made. In meaningful learning, motivation is based on the problem-based intrinsic motivation given birth by the cognitive conflict.

2.2. Orientating- forming an orientation basis

The human being will try to orientate him or herself after having realized the problem. And he or she tries to find, as clearly as possible, a perfect and universally applicable solution to the problem, which will be used to solve problems of the same kind in the future. This kind of solution or explanation model is called an orientation basis. This is perhaps the most crucial stage in learning. What kind of final result comes from learning essentially depends on the nature of the solution formed by the learner. The forming of a good orientation basis is the same as producing a good technical drawing before building a house or making a good pattern before sewing a piece of clothing. If the drawings and thinking models, which have formed, are defective or the patterns are incomplete, the final result will never be the best possible.

The forming of an orientation basis is considered the most important stage in the model of meaningful learning. Orientating in meaningful learning corresponds somewhat to the planning phase in subject matter learning. In subject matter learning we should also pay more attention to the forming of an orientation basis by planning, modeling and all other operations based on anticipatory thinking because they provide the basis for the success of all other operations.

2.3. Internalizing-forming an internal model of the orientation basis.

The orientation basis that has been formed must now be concretized to facilitate internalization. It can be illustrated, if necessary, with the help of a simplified model. The model and functionality needs to be developed through different situations and even supplemented with necessary details. At the same time, required operations models and thinking models are driven on a mental level in a problem or in work because the concrete, external form of the model at the last stage of internalization becomes a model inside the student, which gradually replaces the need for external instruments.

In the model of meaningful learning the internalizing of the orientation basis is a separate stage. The fact that the model of subject matter learning is missing this stage can be considered as its clearest weakness. In subject matter learning, this supposedly at least partly is due to the fact that the functionality of even a detailed plan is not usually internalized well enough before the concrete work starts, nor is enough attention paid to the anticipatory thinking, which should have been included in the orientation stage in the first place.

2.4. Application and use

The real internalizing of the orientation basis requires using it for a longer time period and adapting it as an instrument to solve new concrete tasks. At the application stage, an attempt will be made to use the explanation model in as many ways as possible for the same tasks or related functions. Work related to the orientation basis needs much practice, and at the same time the application must be versatile so that the model can be further developed in similar situations in the future, due to an acquired transfer effect.

In the model of meaningful learning, the application stage is similar to the subject matter, which corresponds essentially to the stage in which the main idea is on the individual work. This stage is based on the adapting of the made plan or of the formed orientation basis in as many ways as possible in the solving of several different tasks and in the further development of skills. At this stage obvious mistakes will seldom be made, but all the mistakes that unfortunately have been made in previous stages accumulate and will be manifested when the actual work begins.

2.5. Evaluation and control

In the model, evaluation consists of two parts: first, a self-evaluation of the matter to be learned and second, evaluation and control of one's own learning. In the first stage, the validity and usability of the matter to be learned, a mental model and the orientation basis will be analyzed, especially from the point of view of practical tasks. The adopted information should give real opportunities to solve tasks of different types and for conscious control and understanding of the connections between matters. The second stage is a matter of evaluation, control and repair of one's own learning. An attempt is made to clarify what has been truly understood, what can be adapted to learn in the future in similar situations and how one can act better next time so that learning can be still more successful.

For the subject matter, the evaluation perhaps emphasizes more the product engagement of technology education, even though, when examining the work that has been completed, an attempt is made to emphasize the pupil's creative solutions and consumer information. The output of one's own learning and the orientation basis that has been used in the evaluation of the matter to be learned are very seldom evaluated.

3. A map of the process of subject matter-based meaningful learning

The phases of a teaching-learning process in both subject matter and meaningful learning were analyzed, and these phases led us to a new teaching model of technology education, which is presented in Figure 2.

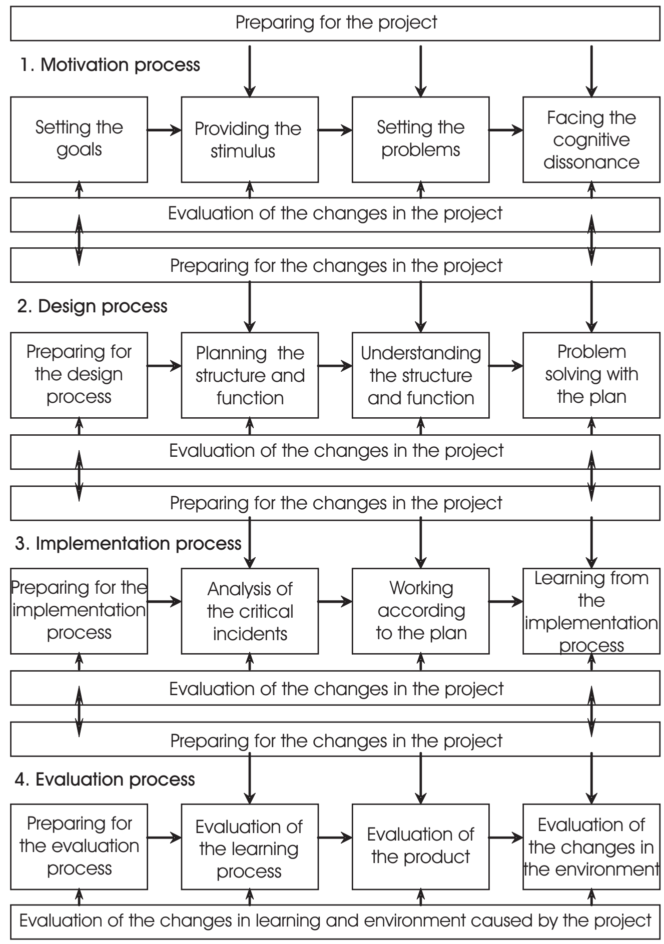

Figure 2. Map of the process of subject matter-based meaningful learning

Much criticism has been made of the over-emphasis on linear, design-process models for classroom practice (Mawson, 2007) and research has revealed that models do not fit, either in reality or in the classroom (Williams, 2000). Even in this model, activities are better called aspects rather than stages of the process. Nevertheless, in this model it is clearly seen that preparation for the project and for the changes in the project is part of the model throughout the entire process. It is also clear that included in every action are some aspects of motivation, design, implementation and evaluation.

4. The Model of Meaningful Learning in Practice

How is meaningful learning realized in practice? This matter was studied in real classroom practices in the University training school of Helsinki. During some practical training periods, the implementation of a couple of projects was followed in an informal teaching experiment. Two projects, the electromagnet and the crane, were more deeply analyzed. Two different classes with about 12 pupils were selected to be video taped. The videotapes were later analysed focusing on the steps of the subject matter based meaningful learning (Figure 2). The next section concentrates on these findings.

Comments made by eleven-year-old students can be found in the next section as examples of a more precise discussion of meaningful learning in practice. More information about the related project, which was carried out in 1993-1996, can be found in Autio (1997) and Autio & Hansen (2002).

4.1. How is the motivation realized?

In the model of subject matter-based meaningful learning, the motivation phase starts with setting the goals for the project. By providing different kinds of stimuli, the teacher tries to arouse the students´ creativity and create an enthusiastic atmosphere for learning. In this way, the motivation is much more likely to be based on problem-based intrinsic motivation given birth by cognitive conflict.

In the classroom practice, the motivation was usually based on the pupil's immediate need or just on the ready model of the artifact to be made. Attempts were seldom made to wake up a real cognitive conflict. On the other hand, the motivation was usually already high enough when starting, and the level of the operation for most of the students never depended on sufficient motivation.

Many researchers share the same opinion, and it is not surprising that both boys and girls are attracted to technology education because they enjoy working with their hands and like the independence and chance for creativity provided by these classes (Silverman & Pritchard, 1996). Students who typically enroll in technology education are attracted to the types of projects they will be engaged in (Weber & Custer, 2005). This was clearly seen in the students´ comments as well. "Yes, I like this work, I can do something. I do not have to just sit down quietly" (Boy11y).

However, it is possible that in the teaching of technology the motivation was quite often based on an external motivation awoken with a product experienced as sensible which often had a clear purpose of use in the student's everyday life. "For example, we made in fourth grade a fine chopping board. Mine was quite fine, and we are still using it at home." (Girl11y). The awakening of real intrinsic motivation with the birth of the cognitive conflict, which is based on solving a problem, succeeded only in few students. "I liked that coil work. It was quite interesting; it is great to see how that magnet really operates." (Boy11y).

The students were also more interested in the product in projects in which the main focus was on learning and not on the artifact itself. "That iron wire circle was not very interesting. I could not really use it for anything." (Girl11y). It was clearly seen, as it has been suggested, that girls are more likely to focus on the social or design function of an artifact, while boys attend to the mechanical function (Benenson, 2001; Silverman & Pritchard, 1996; Weber & Custer, 2005).

Also, in a factor analysis by Autio (1997), a practical advantage received from the product was more clearly emphasized in girls, which for its part would refer to the emphasizing of external motivation. Even though Ryan & Deci (2000) suppose that external motivation can be changed to internal if the project is interesting enough, on the other hand, girls' interest in technology and their knowledge of technology can be improved significantly by developing special programs (Mammes, 2004) where teachers are aware of the differing interests of girls and consider ways of making the environment and the subject attractive to them (Silverman & Pritchard, 1996).

4.2. What methods are used in carrying out the design process?

In the model, the design phase starts by preparing for the planning process by teaching suitable ideation techniques, for example, the principles of technical drawing or circuit diagrams, which are needed in founding a reasonable orientation basis. After that, the planning of the structure and function can begin and the ultimate goal, which is problem solving with the plan or implementation schedule, can be realistically achieved.

In the classroom practice, an attempt was made to emphasize the significance of a reasonable design process, but usually the planning done was more about sketching the product than a systematic problem solution and deepening of the orientation basis. "We made those pictures from the crane, when once it was asked of us, but they did not help much because it was not known however how to make it." (Girl11y). It seems that students more often adopt their own strategies in order to get the job done, while ritualistically using the teachers´ approach to satisfy assessment demands (Hennessey & McCormick, 1994).

Furthermore, technical drawing and the interpretation of circuit diagrams, which should be two of the basic abilities of the design process, were at a fairly weak level. As a result, many students lack understanding about the purpose of a reasonable design process (Rogers & Wallace, 2000).

On the other hand, we must also understand that design development does not only happen with paper and pencil. Concrete modeling with different materials and sometimes even the ready model of the artifact often serve as a sufficient orientation basis for the students. In the later case, the operation may be based only on imitation logic, as it is clearly seen in the next comment. "Those drawings were also quite good of the model, but usually in the end we looked at the concrete machine." (Boy11y). It seems that in these projects the planning was a little bit too technical, and the teachers could not benefit from the finding that at least the girls found the design aspect of the planning more appealing (Silverman & Pritchard, 1996; Weber & Custer, 2005).

In some special areas of technology education (e.g. textile work), the ideation of the output (divergent planning) and the anticipation of different working stages (convergent planning) were more clearly emphasized. Also, the planning functioned excellently in the creation of the orientation basis, which was concrete enough. In some areas of technical work, only convergent planning was emphasized, at least in the projects of this study. In the technical work, the low level of technical thinking (Autio & Hansen, 2002) in several students seemed to hamper creating and deepening the orientation basis required in the work, particularly for technical devices.

The problems in the design stage were not surprising, as several other researchers have noted that there is very little research about design and therefore very little informed guidance in how to teach it (Williams, 2000), and what is more, children are not predisposed to using either drawings (Anning, 1994; Welch, 1999) or plans for guiding their assembly of artifacts (Fleer, 2000; Rowell, 2002). It seems that children prefer to explore with materials first and then move on to modeling (Rowell, 2004).

4.3. How is the implementation stage carried out?

In the model, the implementation process starts by preparing the students to use and understand the tools and techniques needed in the project. Special attention is paid to the analysis of critical incidents. After that, the working according to the plan is more reasonable and realistic, and it is possible to achieve the ultimate target, which is learning from the implementation process.

In the classroom, the working stage was usually the stage that was most carefully carried out. The students were prepared by being taught about certain techniques and tools required in the work. The students were warned about the consequences of probable mistakes thought to be important. In the working process itself, the pupils used their own reasoning, as one student here states. "*When we started, the teacher told us how that crane functions, but there were always quite many other things we did not understand. So we had to think about it more carefully".* (Boy11y). However, in the implementation stage, clear content knowledge and clear planning of the working process were missing, and the work unnecessarily often proceeded through trial and error.

In mere motor coordination, there seemed to be no difference between boys and girls. Nevertheless, in carefulness and exactness it was possible to perceive a clear difference in the girls, if the work was only based on design-related activities and the motivation was high. "If we wanted to put just that thing on that crane, we would manage to do it, and in the end we also had time to polish it." (Girl11y). Consistent with the literature, the females preferred the design activities and found them to be more interesting than did the males, while the males preferred utilizing types of activities (Weber & Custer, 2005; Silverman & Pritchard, 1996).

It was clearly seen that in technology education the most sensible projects for quite many girls were two-dimensional products (e.g. chopping boards and trays) where the significance of three-dimensional perceiving was moderately small and the design aspect was more important. This may later have an effect on the differences between the spatial perception of the girls and boys, but may also explain some differences in the test for technical thinking (Autio & Hansen, 2002). It seems that technical thinking and spatial perception are not much improved by only doing two-dimensional products.

4.4. How is the evaluation carried out?

Evaluation is a part of the model of meaningful learning throughout the entire process, but in the evaluation phase, special emphasis is first placed on preparing the students for the main principles and objectives of evaluation. Later on, the evaluation of the entire learning process and the evaluation of the project or product itself are discussed with the students. Finally, changes in the environment and questions of sustainable development are evaluated. Also, the evaluation of and preparation for the changes in the project are emphasized. Meaningful learning includes anticipatory thinking and evaluation throughout the entire process.

In the classroom practice, the evaluation was very versatile, particularly in the electromagnet project, and it was not based only on the product, such as is often the case. First, the students' finished work was collected together, and a few scattered statements were taken from them. After that, a short discussion reviewing the theoretical basis of the electromagnet was held, and the lifting power of the magnet was tried in practice. Some students even received the task of designing a test for the magnet. It seems that evaluation worked fine in this situation, and the students got a deeper insight into the physical phenomena, *as we can interpret from the next comment. "Then I really understood how that magne*t really worked and how I can make it really strong" (Boy11y).

However, at least a few students did not find the evaluation phase to be successful and essential. "It was quite nice, when we discussed all that work together, but usually we are in such a hurry that we are already starting the next work even though everybody is not ready yet." (Girl11y). The relatively low interest in assessment is consistent with the culture of technology education, which tends to favor application-oriented activities over reflection and analysis (Weber & Custer, 2005).

In the curriculum of the school, self-evaluation was also talked about, but neither any grounds for it nor any readiness to perform the evaluation were found. During the whole implementation process, the students were neither encouraged nor were led to implement the continuous evaluation and the meta-cognitive thinking.

Discussion

Numerous models for curriculum changes in technology education are available nowadays both in technology education literature and school textbooks (ITEA, 2000; Johnsey, 1995). Nevertheless, still an overemphasis appears on passive learning and the old traditions of craft learning (Kimbell, 1997). Materials, techniques and technology have developed rapidly, but the pedagogic contents are regrettably restricted often to only the product to be made. Subject matter teaching has been developed to improve the balance between the product and generic processes, such as motivating, investigating, planning, modeling, making and evaluating.

In the informal teaching experiment focused on in this article, the teaching arrangements applied the model of the subject matter teaching unsystematically and incompletely. The teaching was mostly based on the making of the mere artifact, which was unnecessarily often a copy of the original model. Even though, the ideas of motivation, design, implementation and evaluation could be seen in the teaching, the level of the teacher's material knowledge and control over the devices determined how the operation succeeded from the point of view of the student.

When teaching was examined from the point of view of Engeström´s (1981) model of meaningful learning, the biggest problems were at the internalizing stage. It is difficult to correct matters neglected in the design phase later because the defective mental image makes the operation in the implementation stage much more difficult.

The students' motivation seemed to be very high, and work itself ran smoothly and quickly. On the other hand, more attention would be paid to the teaching arrangements if the motivation were not naturally this high. The pattern of work in the lower classes will later be established and will be difficult to correct, when the underlying motivational problem arises in the future. An attempt should be made to form an intrinsic motivation already at an early stage through an encounter with the cognitive conflict, even if it seemed to be much more difficult than to create motivation based on external factors. However, Ryan & Deci (2000) suppose that external motivation can be changed to internal if the project is interesting enough.

Even though the significance of the design phase was understood and often emphasized throughout the entire process, a practical way to implement it at this level was very seldom found. Merely sketching on A4 paper with a pencil usually did not help the students much in meeting future problems and in internalizing the learning contents. The practice of systematic technical drawing, modeling and the drawing of circuit diagrams should begin much earlier so that a model of rational working can also be obtained at an earlier age. Alternative design methods should also be used more often because children prefer to explore with materials first and then move on to modeling. The planning system of textile work with simple patterns can be considered a good example of this, as it seems to serve as a successful basis for orientation even for younger students. Furthermore, brainstorming and creative problem solving should already be practiced at lower class levels. When students begin the design phase with applications that are useful and simple enough, motivation should also increase.

It is fairly important to put much more emphasis on the planning or founding of an orientation basis because it provides the basis for the success of all other operations. In the beginning, the teaching of proper design techniques is very difficult because it seems that children prefer to explore with materials first and then move on to planning or modeling (Rowell 2004) with the emphasis falling on actual construction, rather than on other aspects of activity, such as design (Cajas, 2001; Schauble et al., 1991).

In general, the working stage was arranged well, and students were motivated and active in their work. The proper mental image and critical targets were usually clarified at the beginning of the lesson, but there were still clear shortcomings in the real internalization of the learning contents. The true content was usually unclear, and so the rational working schedule in the implementation stage was unnecessarily often incomplete.

On the other hand, in the planning stage, the mental image, which had been created only through sketching with A4 paper and pencil, was not complete. Furthermore, the process of internalization was unnecessarily often aided by showing the students a ready concrete model. This was justifiable in some cases, but if this is typical, then the development of students´ own problem-solving capacity is given too little attention and will not develop in the right direction.

It was partly positive that the majority of the students worked completely independently, but on some occasions this was also a negative feature. Attempts to develop the cooperative skills needed in the future were seldom made. Teamwork and the realization of a common group project would better train students for the challenges of working life and would surely reduce the thinking based on the mere artifact.

In the evaluation, a considerably wider process was clearly striven for instead of mere numerical evaluation. The finished work was collected in an exhibition, and based on the executed solutions, discussions about the nature of the scientific and aesthetic points of view of the devices were held. However, quite many students did not find the evaluation stage necessary, and it seems that the relatively low interest in evaluation is consistent with the culture of technology education, which tends to favor application-oriented activities over reflection and analysis (Weber & Custer, 2005).

Much criticism has been made of the over-emphasis on linear, design-process models for classroom practice (Mawson, 2007), and research has revealed that these models do not work in reality or in the classroom (Williams, 2000). The primary focus of this study was to highlight some serious problems in the pedagogy of technology education and try to find some solutions for them. In spite of the criticism, we should try to provide more practical examples that move away from routine activities and low-level thinking. However, it seems that there is still much to do before we pull our ideas into practice.

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