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Exploring the process of inventive learning in technology education

Dr Bernd Hill
Pädagogische Hochschule, Erfurt, Germany

Abstract
Encouraging and supporting autonomy and self-determination as essential characteristics in the process of learning are often seen as central aims of modern pedagogical practice. In this connection the following question should be explored: how can we shape learning experiences in order to reach these learning goals? One possible way forward in technology teaching is to incorporate activities that link technological design work in education to the world of nature. From this rich resource it may be possible to exercise the minds of students in such a way as to encourage inventive learning, leading towards a more autonomous and self-directed mode of general learning.

The teaching that takes place in technology should be presented in such a way that a real understanding of technology can be obtained. This understanding should be of the processes of designing as well as elements of technological knowledge and essential technological principles. It is suggested that by seeking solutions to technological problems through the processes of invention, where solutions are directly linked to analogies in nature, then a deeper, fuller understanding of technology can result. Throughout this learning experience students can examine and use elementary technology by the use of independent strategies, methods and principles of development: the very processes of technological development can be examined.

Biological evolution as a model of change

Biological evolution can be seen as a continuum for permanent change. Under the control of prevailing conditions, modifications to the structure and function of systems occur. These changes are directed towards maximum efficiency. At the higher order of development, such biological systems can be identified by the key characteristics of autonomy, flexibility, and self-determination.

It is evident that more highly developed species are not narrowly specialised. For example, they are not dependent on special food or climate; a capacity for adaptation and adjustment is evident. Also, whilst they do not utilise some of their significant abilities it remains true that they are widely skilled, with no one ability dominating their range of skills. Changes in local environment and the concurrent process of adaptation often give the possibility for such highly developed species to create new beginnings through the recognition and exploitation of opportunities.

Steps of development showing the stages between different levels of biological activity can be deduced from an analysis of the process of evolution. Because biological evolution is a genetic-historical process, specific phases of development have to be mastered in order to progress to a higher level of development. The succession of single, sequential steps of development is not a generally valid representation, but it does shows the basic principle of higher evolutionary development through the formation of new and more complex organisational structures.

Reichel characterises the following necessary stages of development:
1. Aggregation of uniform elements of function
2. Structural differentiation and functional specialisation
3. Hierarchical division of the total function on several levels of function
4. Formation of redundant structures
5. Temporal limited functional autonomy
1.6 Hill

6 Stabilisation of flows of matter and energy by application of the storage principle
7 Parallel assimilation
8 Application of the principle of the conditioned reflexes
9 System compatible information
10 Programmability
11 Ability to learn

An outcome from this process is the emergence of the ability to learn. In the case of highly developed species, passing through these stages is necessary to reach the level of autonomy for adaptation in the face of changing environmental conditions. The ability to learn is often the determining factor that relates to evolution. The higher rate of evolution evident in more developed organisms depends on their relatively large cerebral capacity. If animals make ‘inventions’ and ‘discoveries’ which spread fast by ‘teaching’ and ‘learning’ in the population, a ‘cultural’ pressure of evolution arises. (Piechocki, 1989)

Sheldrake shows that new opportunities can be exploited through changes of behaviour. Advantageous mutations can take these changes in behaviour to higher levels. An example of this process of change is the opening of milk bottles by song birds, with the development of a larger, more appropriately shaped beak. More importantly, it is as a result of the learning process that changes in behaviour occur in a consistent and progressive manner. Mutations can be compared with inventions which subsequently increase the success of a living creature in its culture.

Like other living creatures, man has emerged as a result of the process of evolution. Biological evolution is one key element of the processes of change that have put man in the position to bring forth a new kind of evolution, technical evolution. This step results from human processes of learning. By inventions, man established the means to create an artificial environment. Through this artificial environment, man became increasingly independent of the effects of the natural environment. This is illustrated in figure 1.

Because of the increasing demands exerted by man upon this artificial environment, it is an environment in a constant process of change and development. As a direct result, if we are to maintain our existence, then new and higher demands are placed on the system of education to provide appropriate qualifications and preparation for work. It is suggested that school should educate young people at a very early age to develop attitudes and skills which influence in a positive way the economic, ecological, and social processes of renewal.

School also has to provide qualifications across a wide field, such that the importance of special professional knowledge is diminished in favour of the knowledge of procedures and process. This represents a form of generic knowledge, concerned with skills linked to intellectual processes. The ability of the individual to adopt lifelong learning strategies secures autonomy in the face of the changing world of labour. As such, learning strategies in school have to be delivered and shaped in such a way that they provide opportunities for learners to engage in open problem situations, focussed towards producing flexible solutions.

A strategy of success: inventive learning

Every human being is equipped with a natural thirst for knowledge, manifested in a desire for practical or intellectual activity. In teaching technology we should make use of this characteristic. The conscious learning of strategies that provide proposed solutions in concrete situations can be seen to be more significant than the technological result itself. Not only are significant key skills obtained, but also the fundamental preconditions for effective learning are created. As a consequence, fundamental technological knowledge can be acquired. The process of recognising a technological problem and providing a solution to the problem is at the centre of this strategy.

This problem and acting oriented method of acquiring technological skills requires knowledge of methodology, both for the effective and successful recognition of problems and also for solutions to be created.
Figure 1: the early periods of technology evolution
One method for developing these skills is to support the learner through the use of strategies and methods in technological problem situations. In this framework pupils can ‘re-invent’ technology. By inventive learning we understand the ‘action of re-invention’ as self-finding or self-development in the search for technological solutions. In this approach the focus for pupil activity is a technological problem, provided by the teacher. (Hill, 1995)

The new knowledge which should be acquired by the learner is offered as something unknown, in the form of a technological problem. Acquiring knowledge of technology within the context of a technological design problem takes place as a result of engagement with the design and development process. This approach is shown in graphical form in figure 2.

Specific methodologies can be used to direct and support the transition from the specification of a problem towards a technological solution. If technological activity represents an inventive process, which is pushed forward by creative thinking and action on the part of the human species, then the teaching of technology has to retain a connection with this creative process.

‘Thinking methodologies’ for inventive learning

Mastering a successful transition from the problem situation to the problem solution requires the application of an appropriate methodology. These methodological tools can be suitable for systematically overcoming barriers to thinking.

A suitable methodological approach can be seen to have the following characteristics:

- steps for recognising and solving technological problems (refining and specifying the problem, gaining ideas towards a solution, finding out the optimum solution, shaping and testing the solution);
- principles for development and principles for solving technological problems (features of biological and technological evolution as a heuristic means for the determination of the function of the system and as a source of ideas);
- methods for solving technological problems (black-box-method, lines of development, methods of analogy, of variation, and of combination, methods of evaluation).

The objectives for practising this kind of approach relate to the establishment of a more effective problem solving attitude amongst the learners. At a systematic level, it enables learners to show and to use creative liberty on one side and to produce an ingenious multiplicity of action on the other side.

Characteristics of inventive learning

On a fundamental level, three strands of inventive learning can be identified:

- genetic - technology is an integral part of the human system and our evolution as a species;
- historic - technology is conceived through reflection on the development process;
- prognostic - technology is concerned with future development.

From the didactic perspective, inventive learning can influence and shape technology teaching. For its successful implementation in a teaching and learning context it is necessary to formulate a set of strategic guidelines. In this way, different characteristics for shaping the process can be identified and controlled. The following characteristics represent some of the key features of inventive learning.

- Inventive learning promotes social and individual qualifications.
- Inventive learning is directed towards imparting and acquiring strategies, methods, rules of development and principles of solution for the aim producing a practical solution.
- Inventive learning contributes to the use of contradiction-oriented reflection of the beginning.
Figure 2: strategy: inventive learning
• development, and future outlook of technology.
• Inventive learning transposes the action of acquiring technology (object/process) into the context of a problem situation.
• Inventive learning includes living nature as a source of innovation for developing solutions to problems.
• Inventive learning promotes developmental thinking (systematic, interlaced thinking, hierarchical thinking, analogous thinking, thinking in variants).

Through inventive learning, the objective of generating alternative design proposals during technology lessons can be related back to that situation from which it once originated. The learner will be brought into a similar situation which has been the conclusion from an earlier technological design process. Not only will the technological object be ‘re-invented’, but also important technological knowledge about the object will be gained. At the same time new abilities, skills, and attitudes will be acquired and developed. In this way, inventive learning can expose to the learner the practical and intellectual processes associated with technological development.

Three examples of inventive learning situations that relate to school technology education are described in Appendix A.

Summary
As a process, inventive learning can have a significant role to play in technology education. By reference to biological systems and biological evolution, students can find starting points for the stimulation of design ideas, leading towards the formulation of new design proposals. In the context of education, inventive learning can promote the establishment of generic skills, beliefs and attitudes likely to sustain viable technical evolution.

Reference to new technological problems in the light of associated biological systems provides an alternative addition to the process of technology teaching. Essentially, the teacher has to create the pre-conditions in order to trace back the design task under consideration to examine alternative solutions. Learners can develop creative thinking processes through this examination, whilst mastering the process of providing a viable solution to the design task.

References
Appendix A : Examples of inventive learning in school

**Elementary school**

Problem context: The development, building, and testing of models, which transmit movements by gears.

Objective: The incorporation and understanding of front wheel gear systems.

A suitable possibility of transmission shall be developed for angular, side by side standing shafts.

1.1 Problem: windmill
1.2 Problem: carrousel

**Secondary school**

Developing, building, and testing of models for using alternative sources of energy

Problem context: In an area without electrical energy water needs to be hauled from a well for the irrigation of a field.

2.1 Simple technological solutions for hauling water by means of wind energy are required.

Problem demands:

- continuous taking of water from the well
- guarantee of stopping the hauling movement in spite of strong wind.

Problem context:
Saving of electrical energy requires the concentrated application of natural energy sources. A coppersmith factory situated nearby a river needs to save electrical energy and part of the electrical energy must be replaced by energy obtained from water power.

2.2 Simple technological solutions for using water power are wanted in order to move up and down a smith’s hammer for metal processing.

Problem demands:

- low material expense for the model solution
- accuracy when adjusting the frequency of the hammer.