Integrative education and technological literacy

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**Citation:** BLANDOW, D., 1991. Integrative education and technological literacy. DATER 1991 Conference, Loughborough: Loughborough University

**Additional Information:**

- This is a conference paper.

**Metadata Record:** [https://dspace.lboro.ac.uk/2134/1615](https://dspace.lboro.ac.uk/2134/1615)

**Publisher:** © Loughborough University

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Integrative education and technological literacy

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Abstract
All learning involves the overcoming of barriers. Therefore, one of the roles of education is to frame situations that help people develop abilities to overcome these.

Purpose of the Paper
* to make intelligible the complexity of technology
* to make it clear that we cannot consider the schools as the only learning site
* to present the foundations of a theory of the industry/education interface

It should be obvious that we could simply go on and on about the systematization and processes that are absolutely mandatory if we are to accomplish the challenging educational targets dictated by a society that is seriously concerned about its future and/or even survival. The long-range perspective clearly calls for a changing of the paradigms prescribing the roles of teachers as well as schools. The foundations of the theory we present are intended to enable this shift towards increased integration of learning sites according to the complexity of the environment as a whole.

An important concept can be illustrated by considering the fable about Icarus from Greek mythology - not that school should be considered as an exile or a prison. In order to escape from prison, Icarus and his father attached wings to their shoulders using wax. Icarus, avoiding his father’s warning, flew too close to the sun. The wax melted and he plunged to his death in the sea. He was forced to learn to survive and to translate his wish for freedom into activities. His vision of a palatable future, given the example of the freedom of birds flying over him, triggered his modelling of the wings in the hope of flight and escape.

This example can be considered in today’s situation based on a model of the technology cycle as shown in Fig 1. When a solution is required, we need to be prepared to evaluate it. Icarus built wings in an attempt to escape. The result is known.

The technology activity cycle is important today. The example from the fable shows us today, as it did in the past, the relationship between the tangible world, our mental concepts of it, the initiating value of our concepts/visions, and the power of translating our ideas into practice via a systematic strategy. In Fig 2 we depict the same concepts albeit with the addition of time and economics as further factors to be considered.
Fig 1. The technology cycle

- Problematic situation (thought initiator)
- Overcoming thought barriers
- Imagining a vision of a possible solution
- Model development (resolution of contradictions)
- Development of approach strategies
- Development of time and activity plan
- Execution of the plan
- Evaluation of the results
- New situation/problematic situation

Fig 2 Routes for technological thinking
This example also shows us which barriers we experience in our thought processes and how difficult it is to negotiate them properly - in both the near term and long term. The problematic situation was the starting point/initiator for all activities. Icarus had no concept relating the warmth of the sun to one's distance (i.e. closeness to it). This drives home an important principle -- i.e., to properly judge a situation, technological or not, one must be cognizant of all the aspects of it.

But we don't need to return to Icarus to recognize the lesson of this example. Consider the many calamities and problems we experience seemingly daily: the Tacoma Narrows Bridge collapsed in 1940; similarly, dam disasters, the garbage avalanche, chemical catastrophes (Bohpal), rocket explosions, Chernobyl, the high-rise living silos called apartments, hormone scandals in our food chain, and airplane crashes with a frequency that we have almost become accustomed to them. The world experiences a new Icarus daily! New, however, in that today the consequence of such failures affect all of us, not just a single protagonist. Due to the pervasiveness and power of technology, the consequences are felt by all humanity.

In the case of Icarus he died - i.e., he failed. Therefore, he must have done something wrong. This pattern of error is repeated countless times.

All mistaken developments (e.g. DDT) and operational mistakes (e.g. Chernobyl) are rooted in errors in thinking. The latter are the lowest common denominator of all problems. A second frequent cause of failure typically involves the insufficient consideration of the complexity of the systems and interrelationships involved, and their hierarchical structures. The conclusion is that the development of systems things and the consideration of hierarchical structures represent an unsolved pedagogical problem. A hierarchy of systems is given in Fig 3.

**Fig 3. Routes for technological thinking**

<table>
<thead>
<tr>
<th>Level 6</th>
<th>Cybernetic Systems</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5</td>
<td>Integrated Network</td>
<td>Traffic System</td>
</tr>
<tr>
<td>Level 4</td>
<td>Networked Systems</td>
<td>Taxi System</td>
</tr>
<tr>
<td>Level 3</td>
<td>Systems</td>
<td>Separate cars</td>
</tr>
<tr>
<td>Level 2</td>
<td>Standard Assemblies</td>
<td>Clutch for a car</td>
</tr>
<tr>
<td>Level 1</td>
<td>Standard Components</td>
<td>Transistor</td>
</tr>
</tbody>
</table>

What can be concluded from these examples other than that mistakes are made daily? We need to look more seriously because mistakes can be more serious and affect more people today. The most frequent mistakes are when we do not think enough about the future impacts of current decisions/actions. We think only about the system that contains the object of our decisions/actions. Too
little attention is paid to the system’s link to supra- and sub-systems. This new dimension, namely that systems interact, engenders pedagogic consequences, that the resolution of problematic situation necessarily requires the overcoming of thought barriers. To establish this power to overcome barriers requires a flexibility of approach, and wideness of scope that cannot be accomplished solely in the school - it necessarily requires the active involvement of the use of the whole environment as the place for learning.

Returning to the example of Icarus, it becomes clear that between each of the various problem-solving steps, unsurmounted or inappropriately surmounted barriers exist. Ultimately this causes a failure of the flawed solution. Therefore, schools must proceed differently in the future. In short, they must provide new learning situations as well as new content.

Figure 4. The challenge of industry/education links

The creation of situations, through which learners overcome their thought barriers, and acquire an ability to interpret the world's complex systems, is the most urgent demand of our society's future!

In our view, we also see that the proper overcoming of barriers requires an understanding of and capabilities with ideas, materials, tools, processes, and energy. In short, this is a definition of technological literacy.

Figure 5. Technological literacy

Technological literacy is the ability to properly overcome barriers by the application of an understanding of and capability with, ideas, materials, tools, processes and energy.

Technology is not a discipline that has only one task. Technology is a discipline that helps in the overcoming of barriers by producing the man-made world. Key theoretical ideas:

* The technology as discipline to overcome barriers
* The relationship between barriers and situations

Now, what are the consequences of these two theoretical ideas? What do we see when we canvas the situations wherein we learn?

* Space training stations
* Auto driving simulators
* Table top factories
* Schools
* Classrooms
* Workshops
Obviously, many things are already occurring. What is missing, however, is the development of systems thinking in schools. The interface of schools with industry offers rich potential for ameliorating this situation.

Actually, we could stop at this point.
* The school’s task is to educate
* To be able to learn, one must be able to overcome barriers
* The overcoming of barriers is linked to situations
* Because the environment is so complex today, schools cannot help students learn to overcome the barriers they will encounter in the real world merely by using the abstracted simplified and safer environment created by and in schools.

However, we don't just want to describe the situation and a possible theory - instead, we wish to help. For example, the key competency vectors that define technological literacy Fig 6 represent arrays of capabilities and understandings that help people overcome barriers.

Figure 6. Competency vectors defining technological literacy

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Teamwork, abilities to work in collaboration, able to make compromises, recognize social responsibility.</td>
</tr>
<tr>
<td>2.</td>
<td>Understanding the balance between specialized practical knowledge and skills and system-oriented knowledge and overall both with respect to the Human-Technology interface.</td>
</tr>
<tr>
<td>3.</td>
<td>Capabilities to evaluate technological tasks/activities, to frame decisions and to implement the process of problem-solving/innovation.</td>
</tr>
<tr>
<td>4.</td>
<td>Capabilities for analytical thinking and for formulating technical and technological needs/aims.</td>
</tr>
<tr>
<td>5.</td>
<td>Able to overcome barriers in strategy-oriented problem-solving/innovation processes by mastering the related information-masses through information interpretation, structuring, elimination, acquisition, reduction, combination and evaluation.</td>
</tr>
<tr>
<td>6.</td>
<td>Adaptability for life-long learning and for connecting and reconciling technological, ecological, commercial and social demands and constraints.</td>
</tr>
<tr>
<td>7.</td>
<td>Able to use systems concepts and understand hierarchical structures.</td>
</tr>
<tr>
<td>8.</td>
<td>Able to think in terms of trends and future goals and to integrate future developments into today’s decision.</td>
</tr>
</tbody>
</table>
Similarly, the overview of technology as presented by the modular concept of technology is another key help. The combined model is shown in Figure 7.

- Technological processes, objects
- Technological processes, objects, and interaction sites
- Human-Technological interface constructs
- Problem solving/innovation

**Fig 7** Modular concept of technology
This can be used, for instance, to:

* Consider possibilities systematically
* Assess situations
* Engender systems thinking
* Generate new possibilities
* Structure/catalogue data banks of understandings/capabilities

When we go out of school to use situations from the environment, to be didactically sound, we need a set of understandings that help us use the dimensions of reality to help students learn to overcome barriers. Typically, we believe that students reach into a "modular tool box" of technological processes, i.e., routine ways of interacting with technology, as shown in Figure 8. Note that each tool can itself be taught, practised and enhanced in both school and outside school situations. Furthermore, taken separately each tool can be analyzed and developed to enable more effective instruction, e.g.:

* Trend Analyses
* System Analyses
* Need Aim integration
* Contradictions

Fig 10. The modular tool box

1. Problematic situation
2. Envisioning possible solutions
3. Model development
4. Development of approach strategies
5. Development of time and activity plan
6. Execution of the plan
7. Evaluation of the results
Subsequently, both students and people inhabiting the "other real worlds" then frequently need to use the process of technological assessment. As shown in Figure 9, this involves consideration of a wide range of factors, the consideration of which might prevent the problems previously highlighted.

Fig 9. Technology assessment

Finally, we present the key part of our theory that integrates the problem solving process, the overcoming of barriers and the modular tools needed in the varying situations of real life. This is depicted in Figure 10, entitled 'Model, to identify strategies in real situations'.
Fig 10. Model to identify strategies for real situations

Paradigm change, Systems analysis, Brainstorming.
Need-assessment, Possibilities matrix.
Reverse engineering, Establishing criteria.
Critical path analysis, Implications of new research.
Analysis of technological level, Changing of production conditions.
Quality control, Experiments.
Problem & Criterion analysis, ...
Economic - Technological contradiction

Degree of Abstraction
Composition (Synthesis)
Decomposition (Analysis)

Ideal-Abstract Level

Weak point analysis, Needs assessment.
Trend analysis, Establishing basic function
Determining variables, Establishing and assessing contradictions.
Establishing morphological box, PERT planning.
Dimensioning, Designing, Efficiency/Effectiveness assessment...
Longitudinal tests, Current suitability...

Concrete Object Level

Barriers to the problem solving/innovation process
Tools to overcome barriers to problem solving/innovation

Stages in the problem solving/innovation process
Tools to overcome barriers to problem solving/innovation
Conclusion

It should be obvious that we could simply go on and on about the systematization and processes that are absolutely mandatory if we are to accomplish the challenging educational targets dictated by a society that is seriously concerned about its future and/or even survival. The long-range perspective clearly calls for a changing of the paradigms prescribing the roles of teachers as well as schools. The foundations of the theory we present are intended to enable this shift towards increased integration of learning sites according to the complexity of the environment as a whole.

Appendix

Stages of problem solving/innovation, barriers and paths

Thought initiators, stimuli, needs

1. Problematic Situation
2. Envisioning Possible Solutions
3. Model Development
4. Development of Approach Strategies
5. Develop Time & Activity Plan
6. Execution of the Plan
7. Evaluation of the Results
8. New Problematic Situation

A. Recognition of trends, needs, ...
B. Definition of function, contradictions, ideal system
C. Solution of contradictions, variables, exploration of natural laws
D. Realizing of principles, development of material/energy/information system
E. Dimensioning of the elements/manufacturing/testing
F. Modifying/optimizing the solution
G. Recognition of solution's weak points

Stages in the problem solving/innovation process: 

Main (typical) path

Alternatives paths

Blandow/Dyreneyt/Lutherdt, 1991