Evaluation of Technology Including Effects of Using Technology When Teaching

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Abstract

The ability to evaluate technology, resources, using technology and effects of using it is considered to be a justified educational requirement. It is in compliance with aspects of pedagogical objectivism (for fulfilling external, justified needs) and with aspects of pedagogical subjectivism (for cultivating of consciousness, emotions and being). Also the revised concept aimed at the cognitive domain (being a complex one) puts cognitive process and evaluation explicitly among higher dimension levels. The cognitive dimension of Bloom taxonomy includes four categories: factual, conceptual, procedural and meta-cognitive. It is obvious that the evaluation of technology and effects of its use as educational content of technical classes requires tasks of high appraisement.

This contribution focuses on the topic of evaluation of technological resources and effects of using technology; first, from a teachers perspective who must handle this topic successfully to educate a student plus from the point of view of educational goals and tasks and second, from the perspective of a student. This contribution analyses teacher’s approaches towards the matter and ways of evaluating specific technological resources for educational purposes and for future practical use as well.

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1. Introduction

It is generally accepted that technology is widespread and that it has both positive and negative effects. A school is supposed to prepare a pupil for thinking about technology and for effects of using technology during individual activities and activities within vast communities. This educational requirement is acceptable for

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pedagogical objectivism due to the aforementioned “external need” and this kind of education seems acceptable also from the pedagogical subjectivism point of view Blížkovský, B. (1996) which seeks cultivation of human consciousness, experiencing and being. Therefore, it can be stated that education aimed at evaluating technology and at effects of using technology can mean preparing pupils for the external world and their inner cultivation.

Today’s conception of education is based particularly on emphasizing individual needs of a pupil regarding his/her future career. Each individual can fully develop his/her abilities only in a society which is able to learn and to react flexibly on occurring changes. Education as a manifestation of socio-cultural and economic dimension is nowadays related to using modern technologies in all aspects and areas and this will not change in the future – on the contrary. As an example, we can mention an already common phenomenon of a “virtual class” or schools educating “avatars” Marešová, H. (2009). Technology has been playing an increasingly important role in education when also carrying out non-traditional forms of education, such as education with no time and space constraints. Technology is employed in setting-up means for organizing education, but it also exceeds the content of education.

2. Evaluation of Technology and Evaluation of Effects of Using Technology

Technology, technical solutions and ways of creating/using technology and disposal of technology must be evaluated first from the point of view of appropriateness and then from the point of view of potential of a technical solution to meet expected objectives and furthermore, generally, from the point of view of effectiveness and maximizing benefits. Related form of evaluation from the point of view of minimizing negative effects is also important – see Löhr, J.-P. (2012). If a purpose for using technology is justified, there are usually more technical solutions for fulfilling a purpose; plurality of technical solutions is one of the basic features of technology Wolffgramm, H. (1994). It means that it is necessary to pursue solutions that are optimal regarding criteria corresponding to acknowledged values. If technology is not mere consumption, but if it represents important factor in a life of a person and society, it should be treated accordingly. Using technology is not only about technology itself and a method of use, but also about a user who can be for instance still a pupil.

It cannot be denied that a method of creating and using technology is mainly influenced by users themselves. Their activities determine the state of technology, possibilities of using technology and last but not least effects of using technology by people without specialized training. Decisions of professionals are driven by many regulations, norms and existence of control bodies and mechanisms available within the decisive sphere. However, technology is mainly evaluated by its users who are non-professionals. Let’s introduce evaluation of technology and effects of its use in general terms first.

In this paper, the method of “professional” evaluation is of interest, which eventually leads to prevention of pollution, limitation of emissions and its effects on environment, and which is based on a demand of Best Available Techniques (BAT) use. The list of these techniques is available in the referential documents BREF (Reference Document on Best Available Techniques) which have been elaborated for individual categories of industrial fields, see (Referenční dokumenty BREF). Each BREF document includes for example production characteristics, description of techniques and used methods, level of emissions, and raw material and energy consumption. Permitted technology must comply with these norms. The directive states the following: „best available techniques shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole [...]”

The aforementioned is an evidence of the fact, that evaluating technology and evaluating effects of its use is narrowly related and that technical as well as non-technical criteria are used for evaluating appropriateness of technical solutions. This corresponds to the most important feature of technology/technologies which is the relationship of scientific and social aspects (Wolffgramm, 1994). Each technical object, system or procedure is based on practical use of scientific processes, phenomena, rules and possibilities of nature. Social aspects also play a role, although they can seem indirect and non-mandatory. Scientific laws delimitate space for technical solutions, but the choice and pace of creating and using technology
depends on social and human needs, recognized values and approaches, possibilities, moods, trends, etc., that is simply on social factors. This is related also to broader context or aspects of technology; they are asserted as various “non-technical” requirements for running technical objects and for technology. These aspects do not constitute a homogenous group as far as their importance is concerned. The most important are those whose compliance is obligatory – safety, healthy, fire protection, ecological, etc., then those which have less severe consequences – economic, cultural, social and political aspects and also ones concerning raw materials, material and energy, see also (Kropáč & Stoffa, 1997), (Kropáč, 1998, pgs. 6-7).

The procedure of continuity in evaluating technical solutions is well formulated (from the point of view of application in education) by Banse (2008). The concept is based on so called “technological funnel” (der technologische Trichter), an idea of a tunnel “being filled with technological solutions”. Before “filling it in”, appropriateness of a purpose – creating a need for a solution – is considered. Afterwards, the technical solution must hold up to many evaluating questions, which is the way how inappropriate solutions are excluded. Here is a list of several framework aspects chosen from many subsequent evaluating ones:

a) evaluation of a technical solution from the point of view of current possibilities within science;
b) evaluation from the point of view of technical or technological feasibility;
c) evaluation from the point of view of economic and ecological feasibility;
d) evaluation or assessment from the point of view of social, legal, political and ethical justifiability.

The presented evaluation of technical solutions is usually carried out for the selection of purposes and for specifying originally unclear purposes requiring a technical solution. Important criteria used for technology evaluation during this procedure are (Banse, 2008):

- functionality;
- safety and stability of its function;
- health and safety;
- non-damaging public environment;
- cost-effectiveness;
- efficiency;
- contribution to „personal development and social quality”.

It is important to emphasize that when considering technical solutions it is necessary to exert so called preliminary precaution, because prior to employing technical solutions we have the least information about possible solutions and its effects in given conditions and the most options. During the process of employing technical solutions the amount of information about results and effects increases, but the possibility to make changes decreases by costs that have been already spent.

Within the general term technology evaluation or a broader one – technology (in the sense of technical objects and technology use), we can differentiate various partial aims of such evaluation. This is aptly described by Löhrl, J.-P. (2012); and the preceding parts of this paper and its title have also touched upon the partial aims. These aims can involve focusing the evaluation on assumptions regarding whether technology and technical solutions can meet expected purposes; it concerns modernity, effectiveness and stability of use, etc., and naturally it can also involve broader effects of technical solutions and technology use. More important aspects are, however, technical ones. It is not necessary to prove particularly that for example today’s technology of a good quality constitutes a requirement for ecological and economic solutions, i.e. that “technical and non-technical” aspects of evaluation are related; however, when incorporating the subject matter into education, this sort of analysis becomes important.

We can also see a difference in whether the evaluation concerns only technology in a narrow sense (technical objects of material nature), or whether it concerns methods of employing technology/ways of use. In case of evaluation focused mainly on technical objects as such, it is obvious that primarily „technical” aspects are taken into consideration (for example various tests of cars, electronics, etc.). Wider context is surely also present – fuel consumption of a car is both a technical and an economic aspect and a car must attract buyers. When evaluating operation and use of technology, broader context of technology becomes more important along with increasing
attention paid to effects of operation/use. To put it simply – to evaluate an axe as a technical object, it requires consideration of many technical aspects, such as firmness, hardness, sharpness, etc., which determine use of an object. To evaluate use of an axe, it involves mainly evaluation of the appropriateness of the purpose from the social point of view and evaluation of use from the safety, ergonomics and economic point of view; moreover, an evaluating person would probably include also his/her personal competence in working with tools.

This still pertains to evaluation of technology and technical solutions, but depending on the specificity of evaluation (e.g. effects of use), an importance of different points of view, criteria and aspects change (Dostál, Serafin, Havelka & Minarčík, 2012). This fact is illustrated by the following figure (n. 1), characterizing an approach to evaluating technical objects by male vs. female teachers who focus on areas of technical training of pupils in teaching. It can be seen that individual criteria represented by the dots are perceived differently by the two groups, although the difference is not significant.

![Fig. 1 Comparison of evaluation of technical objects by male vs. female teachers (blue – male, red – female).](image)

Deviation from purely technical aspects when evaluating operation of technology (technologies themselves, usage) can be seen in case of evaluating technology by a proper professional and a common user. Stoffa and Procházková (1997) divide users of technical objects into a group of laymen and a group of professionals. Due to technology spreading and increasing specialization of professionals, it is common that non-professional relations to technical objects outside professional specialization emerge. In that case, laymen as well as technical professionals working with technology outside their scope of specialization are common users of technology. Common users usually have more options regarding ways of using technology or conditions for using it. Basic evaluative questions can be for example the following:

- When buying technical objects: Are they appropriate for a specific purpose? Are they compatible with already owned equipment? Are they economic and ecological? Are they safe? Are they recyclable?
- When using technical objects: Are optimal conditions for proper functioning provided? Are safety rules complied with? Is sufficient maintenance ensured?
- Disposal of technical objects: What is „the most ecologic and economic” procedure?
This shows that also a common user thinks about alternatives to a solution and/or declining a solution. What is undoubtedly important for proper use of technology is general, comprehensive technical knowledge and related competence in identifying deficiencies and risks, but also results of further general learning, knowledge and a created personal value system regarding nature and society.

3. Evaluation of Technology and Effects of its Use – Educational Context

General technical subjects, mainly those taught at primary schools, are mostly aimed at common technology users / laymen. The purpose of this kind of education is to prepare pupils for problematic situations connected to technology use they might encounter in the present or in the future. Efforts to relate technical matters with broader context, technology evaluation and effects of technology use must be significant, which also counts for exerting critical thinking in relation to technology. A pupil will encounter problems associated with technology in his/her personal life, such as „should I buy a robotic vacuum cleaner / a car?”, or „should I replace my car, air conditioning, coffee machine, kitchen equipment, bicycle, and if so, for which type?” „How am I supposed to use them?” A pupil should think about effects of using technology, reminds Löhr (2012); and also about his/her individual possibilities of acquiring certain technological object and of using it (for instance financial possibilities).

Evaluating technology as an important part of life is also related to a civic aspect, i.e. wider social practice. A growing importance of a citizen’s opinion on various offered solutions (highways, energetic buildings, incinerators, dumping grounds, etc.) can be assumed. In this case, the right of a citizen to express himself/herself must be associated to elementary knowledge and cultivated ability of evaluation.

Evaluation of technology from different points of view including broader context can be thus considered to be a justifiable educational requirement. Education aimed at evaluation of technology can be in compliance with perspectives of pedagogical objectivism due to “external needs”. It is needed also for seeking cultivation of human consciousness, experiencing and being – which come under pedagogical subjectivism. A revised concept of Bloom’s taxonomy focuses on the cognitive domain as a complex one (e.g. affective goals are derived from the cognitive ones, because a cognitive goal involves affective context). The revised taxonomy is two-dimensional; one dimension represents cognitive processes which can take form of remembering, understanding, applying, analysing, evaluating or creating, and the second dimension is a dimension of knowledge with four sub-categories – factual, conceptual, procedural and meta-cognitive. It is obvious that evaluating technology as a subject matter of general technical subjects requires tasks with high level of rating within both dimensions. It should be also taken into account that Bloom’s taxonomy is partly considered to be a cumulative one, i.e. higher categories can be developed only when lower categories are mastered adequately.

The above mentioned aspect of evaluation of technology itself, and if need be, also the aspect of technology use require educational tasks such as means for evoking learning activities of pupils in the educational process. These activities are created by a teacher in the pre-interactive phase of education, always with certain didactic objectives.

On the basis of results of former research carried out at our workplace we will attempt to complement briefly the subject matter of the present paper. The research was mainly focused on analyzing possibilities of increasing effectiveness in teaching electro-technical subjects at upper secondary schools using learning tasks.

The Q-methodology was used as a research method for gathering subjective opinions of teachers (teaching specialized electro-technical subjects at vocational schools) on importance of individual measures for improving effectiveness of the teaching process. According to Pelikán (Pelikán, 2004; pgs. 138-143), it is a research means based on W. Stephenson’s methodology. It lies in a combination of rating, psychometric and statistical procedures that serve not only for gathering data from respondents, but also for analysing correlation between answers of various respondents and presented Q-types. This method is specific due the fact that a respondent is “forced” to distribute his/her answers on a scale so that they correspond to Gaussian distribution. This method makes a respondent take a rather more defined stand towards presented phenomena and avoids quite a common tendency of respondents to evaluate phenomena by an average rating (e.g. in case of scales). Furthermore, the Q-
methodology – in comparison with other qualitative methods – allows to use fewer respondents, but on the other hand it brings a disadvantage, because it is more time-consuming regarding the interaction with respondents and further statistical processing (Chráska, 2000; pgs. 154-157).

After a complicated process of determining the broadest possible spectrum of factors influencing the aforementioned phenomenon, the following 7 areas were specified:
1. factors creating educational conditions;
2. basic objective factors of the educational process – aims and content of education;
3. basic subjective factors of the educational process – a teacher and a pupil (pupils), their stable long-term personal features and social interaction;
4. pre-interactive phase of the educational process;
5. interactive phase of the educational process – the content;
6. interactive phase of the educational process – the process;
7. post-interactive phase of the educational process.

For the research purpose, individual Q-types were defined in these 7 areas and some of the Q-types included also the above mentioned broader context of technology. To avoid respondents being influenced by the order of Q-types when sorting them, the Q-types were given random numbers from the total set of 60. Individual Q-types (effectiveness aspects) were formulated as external measures by which higher effectiveness can be achieved during the teaching process. Teachers were given this task:

„Express your personal opinion on the subject matter formulated by the following question: How important is the content presented on individual cards for increasing effectiveness in teaching electro-technical subjects using learning tasks?“

The task was given to teachers of specialized electro-technical subjects from 34 vocational schools – in total, there were 149 respondents who can be characterized as follows:

- according to sex: 122 men and 27 women;
- according to obtained university degree: 127 graduates with an engineering degree; 13 graduates of a faculty of education; 2 graduates of a non-teaching Master’s degree (graduates of a faculty of science); 3 graduates with an engineering degree who graduated also at a faculty of education (2 cases), or obtained a Bachelor’s degree in teaching (1 case); and 4 respondents who chose an option “other”.
- according to a degree from complementary pedagogical studies by graduates with and engineering degree: out of 127 graduates with an engineering degree, 94 had a degree in complementary pedagogical studies (i.e. 74.02%), 30 didn’t have a degree in complementary pedagogical studies, and 3 graduated at a faculty of education – Master’s or Bachelor’s degree (i.e. 2.36 %).

To determine the reliability of the questionnaire, the level of internal consistency was measured by so called Cronbach’s alpha (the measured value was 0.967). This value was further verified by the bisection method (the measured value was 0.0955). In both cases the measured value of a coefficient was higher than a limit value of 0.70 and the questionnaire can be thus considered reliable.

From the total number of 60 Q-types, 7 of them were identified as items related to broader aspects of technology and its use, involving the aspect of evaluation of technology use; it concerns the following Q-types: Q34 Presented learning tasks are aimed at solving issues related to practice (The matters that are dealt with are useful for a pupil in his/her future career); Q18 A pupil is led to seek practical use for study matter; Q16 Tasks are formulated in a way that a pupil can effectively use various sources of information (books, catalogues, instructional literature, dictionaries, encyclopaedias, magazines, media, internet, educational programmes, multimedia, etc.); Q12 A pupil is constantly supported in developing the ability to formulate hypotheses of solving given or encountered problems and verifying their validity; Q19 Interpretation and analysis of a solution by a student is a part of the solving process; (A pupil deduces a meaning of a solution and conditions for its validity); Q31 Pupils are given problem-solving tasks (unusual tasks, i.e. tasks with an algorithm of a solution to be discovered;) and Q5 Pupils are given tasks aimed at divergent thinking, i.e. task with more possible solutions (A pupil must find individual solutions and explain the conditions in which they are valid).
Table 1 shows that 3 of the above mentioned Q-types are placed in the first third according to the average evaluation, 1 is placed in the second third and 3 in the last third.

On the basis of this part of the survey, it can be demonstrated that respondents did not express any defined stand towards the aspect of evaluating technology and operating technology.

The focus on the matter of evaluation of technology allows and requires discussion during classes. Topics of such discussions can be various, depending on the maturity of pupils; some of the easier objects can be for example a faucet (classic vs. lever one), light sources and types of heating of buildings plus their advantages, disadvantages and overall evaluation. A discussion about complicated technical objects is, according to teachers’ experience, possible only after adequate preparation and with careful observation of constructiveness of a discussion; topics such as ways of producing electrical energy, combustion of municipal waste, automation and its effects, genetically modified food, construction of high buildings and intelligent building management can lead, according to teachers’ experience, to more tense discussions and also require deeper knowledge of a matter.

Technology can constitute separate educational content – a topic focused on evaluation of technology, especially evaluation of technical objects using “technical criteria” in relation to technology use. In this case, the matter can be an organic, direct part of technical subject content. This sort of education answers questions such as “what should good-quality technology look like?”. Also in this case, the broader context of technology and related effects of using technology cannot be omitted and links should be made with vast knowledge from other school subjects. An example can be our recent research focusing on project education realized with real technical objects in which this kind of education was compared to the traditional type of education (when knowledge is “transmitted”). Both approaches are showed in Table n. 2; the group of respondents was composed of 4 classes of 8th grade (14-year-old pupils) (E1, K1) and 9th grade (15-year-old pupils) (E2, K2) of lower secondary schools. Classes with worse study results were set as experimental (E1, E2) and classes with better study results were set as control ones (K1, K2). The results show that pupils in the experimental classes (E1, E2) taught by the project method using real technical objects reached statistically better performance in remembering than pupils in the control classes (K1, K2) taught by the traditional method.

Table 2. Results of the analysis comparing the two methods of education.

<table>
<thead>
<tr>
<th></th>
<th>E1</th>
<th>K1</th>
<th>E2</th>
<th>K2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average performance</td>
<td>9.48</td>
<td>8.13</td>
<td>10.07</td>
<td>8.73</td>
</tr>
<tr>
<td>Median</td>
<td>9</td>
<td>7</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Systematic variance</td>
<td>28.46</td>
<td>26.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random scattering</td>
<td>2.25</td>
<td>2.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated value of a test criterion ( F )</td>
<td>12.65</td>
<td>11.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical value of a test criterion ( F_{KR} )</td>
<td>7.08</td>
<td>7.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degrees of freedom ( \nu_1 )</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degrees of freedom ( \nu_2 )</td>
<td>60</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of significance ( \alpha )</td>
<td>0.01</td>
<td>0.01</td>
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</table>
Evaluation of effects of technology use and broader context of technology are mainly represented in education as aspects of “other topics” on technology that they are related to (evaluative criteria of appropriateness, quality, effectiveness and its use). It can be for example an aspect of environment protection in classes about combustion engines, cost-effectiveness when working with technology, an aspect of work safety when working with technology, etc. Teaching about technology would be incomplete without this kind of broader context and the above mentioned evaluative approaches.

What should be, in general, included in education, what links should be created, what should be done, what questions should be asked, what topics should be discussed. It can be the following, also in accordance with Löhrl, J.-P. (2012):

- questions about the purpose of technology and thinking about generally acknowledged values in relation to technology, operating technology and using technology;
- clarification of the relation purpose-means, i.e. what is the purpose of certain technology or an activity, is it justifiable, is certain technology or an activity a good means for achieving certain purpose or for satisfying a rightful need;
- to activate and enrich a system of positive, generally acknowledged values in pupils’ minds and to prepare pupils for using them;
- to critically assess problems related to technology use; to choose ways of using technology based on up-to-date knowledge; to accept justified decisions;
- to assess actions from rather broad context; to encourage pupils to be responsible for their own actions, including actions related to technology use;
- to help pupils create an idea about their own abilities to use technology which is important for decisions about their future career;
- to contribute to an overall overview about possibilities and limitations of technology;
- to teach pupils how to deal with the world of technology;
- to prevent that pupils create dependency on technology (digital technology, gaming machines, etc.);
- to improve vertical integration of education (linking theory with practical use);
- to improve horizontal integration (links between subjects);
- to help pupils with creating a positive dialogue in the sense of critical thinking based on arguments, not a destructive dialogue in the sense of “detached” thinking about technology.

The above mentioned procedures are valid if they are based on generally acknowledged values and current knowledge. Subsequently, teachers can also present standpoints to delicate issues such as a feeling of freedom in the technical world (surveillance, dependency on technology) where the feeling of freedom or lack of freedom is related to preparedness to live in such a world.

4. Conclusion

Technology is sometimes considered to be neutral in terms of values, because only a user decides about its use. This statement is too simplifying. Today’s technology is powerful and effective, but can be dangerous as well. It is thus necessary to teach about technology and evaluate its use from different points of view and contribute to pupils’ responsibility. In this specific context and the context of above mentioned facts, it is obvious that there is a strong potential to educate pupils and the term technical education is appropriate.

Incorporating topics related to evaluation of technology and effects of its use into education allows teachers to employ constructivist approaches for personal development of individuals. Such an educated individual does not adopt other peoples’ opinions, but actively constructs his own ones and compares them with the external reality surrounding him. He is not a mere uncommitted observer, but thinks in the context of objective and subjective facts; considers what is appropriate/acceptable and what is not, especially regarding matters that are closely
related to him or influence him. In the evaluation process a value framework is created which has an effect also on subsequent evaluative processes. This leads to versatile and necessary development of technical thinking, constituting a regulative aspect of thinking about technology. Development of critical thinking about technology also makes an individual to evaluate himself regarding ability to use technology.

In the field of education, evaluation as a part of educational content has a direct link to information technology education where pupils, in order to be able to evaluate technology, learn to search for information, differentiate between useful and useless information and process information and use it. They must be able to acquire information without which the evaluative process would not be feasible. Information should be as objective as possible and it should reflect the external world in a way that a value framework created by a pupil is consistent, long-lasting, but also flexible regarding new facts.

References


