

Does interactive learning environments in physics promote diversity or marginalise students?

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ABSTRACT

Different designs of learning environments facilitate different opportunities for students to learn. In this paper a study how different designs of laborative learning environments in physics using interactive technologies give students various opportunities to learn will be reported. In particular it is focused on this in relation to the diversity we have in a student population and in society. It is seen in the data that the opportunity to learn for different groups is closely related to the design of the learning environments. Some designs seem to give most students opportunity to learn while other seems to favour and disfavour certain groups. In this context the concept of educational accessibility is introduced. It is argued that we from the beginning have to have this concept in mind when design learning environments.

1. INTRODUCTION AND FRAMEWORK

In the personal view of the author of this paper it is important to make science “accessible” to “all” students (cf., McGinnis & Stefanich, in press). This is seen as a question of democracy (cf., Skrtic, 1995; Smith & Erevelles, 2004) – all students should have the possibility of personal growth and to follow their interests regardless of sex, ethnic background, functional impairments etc ... In this context it is important to investigate the possibilities for learning in different learning environments for different groups – are certain groups of students excluded or marginalised? Our view is in line with Dewey (1916) who points out that “democracy is more than a form of government; it is primarily a mode of associated living, of conjoint communicated experience”.

This work is also situated in the intersection of two larger studies in educational design and research: One is the study of accessible learning environments utilising “digital tools” (e.g., Schenker & Scadden, 2002; Schenker, 2003; Schenker & Bernhard, 2006). The other is the study of learning environments in physics and in electrical engineering utilising “interactive technology” to develop conceptual labs (e.g., Bernhard, 2001, 2003, 2006; Carstensen & Bernhard 2004). A common denominator in these studies is studying the role of computers as “tools” for learning which the terms “digital tools” and “interactive technology” refers to.

An important theoretical background to this study is the concept of tools in the socio-cultural theory of learning (e.g., Vygotsky, 1978; Cole, 1996; Kozulin, 1998). Much of human interaction with the material and social world is not direct but mediated through the use of mediating tools that could be expressed as:

Human ⇔ Tools ⇔ World.

These tools could be of different types such as “psychological tools” or artifacts and these makes more powerful and functional ways of acting possible.

Pointing out that we “think through technology” is also expressed by Mitcham (1994) in a book with the same title and in some schools in philosophy of technology extending the works of either Dewey (see for example Hickman, 1990) or Ihde (e.g. 1983). Verbeek (2005) further extend this and according to him

The concept of mediation helps to show that technologies actively shape the character of human-world relations. Human contact with reality is always mediated, and technologies offer one possible form of mediation. On the other hand, it means that any particular mediation can only arise within specific contexts of use and interpretation.

Similarly Heidegger (1954/1977) points out that it is well known to any experimental physicist that:

Modern physics, as experimental, is dependent upon technical apparatus and upon progress in the building of apparatus.

The so-called Microcomputer Based Laboratory (MBL) is an example of the use of “interactive technology” as a tool in physics education (Tinker, 1996). MBL was introduced into physics teaching almost three decades ago. In MBL activities students do experiments using different sensors (e.g., force, motion, temperature, light and sound sensors) connected to a computer via an interface. The arrangement creates a powerful system for *simultaneous* collection, analysis and display of experimental data, which sometimes is referred to as *real-time* graphing. This setting allows development of labs which can be effective in fostering functional understanding of physics (e.g., Bernhard, 2001, 2003, 2006; Hake, 1998; Sokoloff, Laws & Thornton, 2007; Thornton, 1997; Tinker, 1996).

In the context of discussing *science for all* the concept of *accessibility* is important. This concept is often used in relation to persons with disabilities. Do-It (no date) defines the concept it in this way:

Accessibility sometimes refers to the characteristic that products, services, and facilities can be independently used by people with a variety of disabilities.

Since the aim of a learning environment is that it should facilitate learning in relation to some “intended object of learning” (Marton, Runesson & Tsui, 2004) it would be natural see accessibility of a learning environments in terms how well it give individuals in a diverse student body an opportunity to learn. However according to Norman, Caseau and Stefanich (1998):

Specialists in adaptations look only at physical accessibility and mobility, not the special [educational] needs of the disabled student, which may require adaptations for hands-on science investigations.

As long as the main problem has been to even gain access to lecture halls, labs and other facilities it is understandable that the physical accessibility of an educational setting have been in focus. However, we would argue that it is necessary to take this concept one step further. It is not enough to gain physical access to the learning environment; the content to be learned must also be, as McCutcheon (1982; cf. Cherryholmes, 1988) states in the citation below, made learnable for students:

By curriculum I mean what students have an opportunity to learn in school, through both the hidden and overt curriculum, and what they do not have an opportunity to learn because certain matters were not included in the curriculum ... Examples of aspects of the enactment of the curriculum might include ... how teachers and materials render the curriculum *accessible* to students; the received curriculum (the sense students make of it); ... and what students learn through ... curriculum. (My italics)

We would propose a concept, *educational accessibility*, which is related to the extent an enacted curriculum, the “enacted object of learning” (Marton, Runesson & Tsui, 2004), gives different students an opportunity to learn – i. e. if the content is made learnable for different individuals.

The concept of educational accessibility is not a collective concept that measures how the learning environment gives the *average* “typical” student an opportunity to learn. Rather the concept gains its meaning as a relational concept describing what opportunities for learning are made possible in the relation between the learning environment and different individuals or distinct group of individuals.

If we are interested in the issue of *science for all* and *educational accessibility* of a learning environment we have to investigate how the learning environment meets a diverse student body. Does the design of the learning environment give most students an opportunity to learn or are certain groups favoured or disfavoured? Does the learning environment promote diversity or are certain groups of students marginalised or excluded?

2. METHODS AND SAMPLE

As mentioned above this study is partly situated in a larger study investigating the design of conceptual labs. We will present data from five different learning environments in university physics.

Case 1, 2 and 3: In these cases (Engineering students, Mechanics I) MBL-labs were implemented as “conceptual” labs meaning that the labs emphasized concepts and connections between different concepts and the active engagement of students. The educational approach is multimodal and the design was inspired by, but not identical to, the approach used in *RealTime Physics* (Sokoloff *et al* 1998, Thornton 1997 and references therein). The design of the lab-sequence is described in more detail elsewhere (Bernhard, 2001, 2003, 2006a, 2006b). In case 3 a smaller set (four 4 h labs instead of seven 4 h labs) of the labs from case 1 were implemented within a larger course and 25 students of a total of 125 students volunteered to take MBL-labs. The number of students in case 1 and 2 were 40 and 20 respectively.

Case 4: Pre-service Teachers 98/99. The original MBL-labs were transformed into formula verification labs. For a more detailed discussion see Bernhard (2003, 2006a). In this case 31 students participated in the course.

Case 5: Finally in this case is included the remaining 100 students from the same course as in case 3. Case 3 and 5 had the same lectures and the same problem solving classes but different laboratory curricula. It should be noted that the only difference between these cases is 16 h of labs!

Classical mechanics have been a major topic in all the physics courses studied and to get an indication of student's conceptual understanding the Force Concept Inventory (FCI, Hestenes, Wells & Swackhammer, 1992) or Force and Motion Conceptual Evaluation (FMCE, Thornton & Sokoloff, 1998) have been used as instruments. The tests have been administered as a pre-test at the start of the course and as a post-test at the end of the course. Averages, gains and normalised gains (Hake, 1998) have been calculated from test data for the course as a whole. Gain is the difference between pre- and post-test values and normalised gain is the actual gain divided by the maximum possible gain. The normalised gain is an important measure because it makes it possible to compare different courses with different pre-test result (Hake, 1998).

In most studies discussing the effectiveness and non-effectiveness of different implementations of MBL, and other learning environments in physics, only data for the whole student body as a collective have been presented. Typically not even gender differences are discussed. However, to study issues related to how different groups within the student body are met by the learning environment one has to do a more fine-grained analysis. To discuss the question of marginalisation and opportunities for learning we have re-analysed our data. Part of my analysis will be presented in the next section.

3. RESULTS FROM SOME DIFFERENT LEARNING ENVIRONMENTS IN PHYSICS

In table 1 and in figure 1b is displayed a comparison between the gains for male and female students. In table 1 and figure 1c are also gains differentiated with regard to students results on the pre-test presented. Except for case 1 the gain is calculated using a matched sample (only students who participated in both the pre- and the post-test are regarded when calculating gains) but in case 1 it was

not possible since in this case the students took the conceptual test anonymously. For this reason it was also not possible to differentiate the data from case I with regard to pre-test results.

Table 1. Calculated normalised gains for different learning environments according to the FMCE-test.

Approach	"Conceptual" labs			"Non-conceptual" labs	
Technology	Interactive technology labs				Traditional labs
Group	1. Engineering 97/98	2. Pre-service teachers 00/01	3. Engineering MBL 02/03	4. Pre-service teachers 98/99	5. Engineering trad. 02/03
N (in course)	40	20	25	31	100
Male	62%	78%	66%	41%	24%
Female	55%	51%	38%	26%	11%
Pre-test \leq 30%		55%	36%	24%	14%
Pre-test $>$ 30%		75%	70%	46%	30%
All	61%	61%	52%	34%	20%

A typical way of presenting the results from developing innovative curricula is presented in figure 1a. From this presentation it looks like that case 1 and 2 are equally successful with case 3 closely following up. However the data presented in figure 1b and 1c tells a different story. Case 1 seems to have given the male and female students almost the same opportunities for learning, but in the other cases the gap between male and female students increases. Also the results displayed in figure 1c show that the gap between students with high or low pre-test scores increases. However in this case it should also be noted the differences between the learning environments. The low-pre-test-students in case 2 and 3 have higher normalised gain than the average normalised gain in case 4 and 5. In the next section we will relate our findings to question of normality and marginalisation.

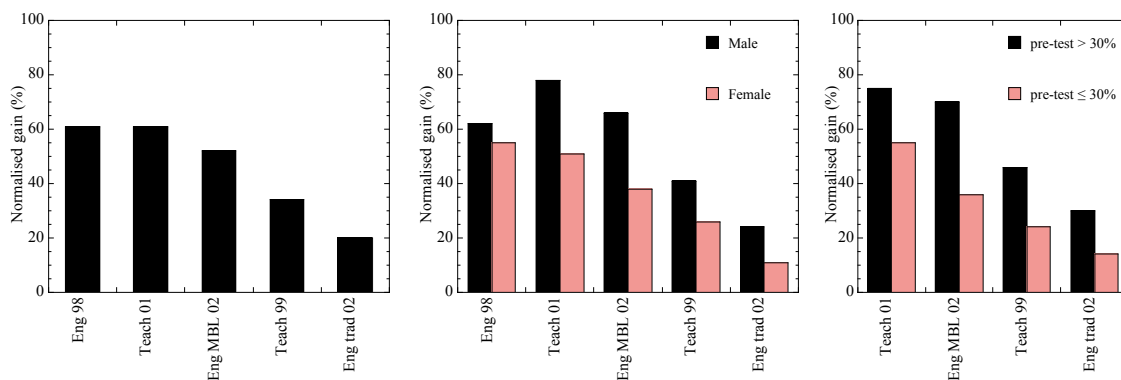


Figure 1. Normalised gains for the different cases described in the text divided by group (Thornton & Sokoloff, 1998).

4. CONCLUSION, DISCUSSION AND IMPLICATIONS

The results presented above indicate that some curricula increase gaps between groups of students while other curricula seem to give most students an opportunity for learning.

On mainly theoretical grounds it has been argued that MBL would be well suited for students with

disabilities (Bernhard & Bernhard, 1999). As mentioned in the introduction good learning results have been reported from learning environments utilising MBL. However, as demonstrated in a comparative study, using quantitative methods, by Bernhard (2003) not all uses of MBL are equally effective. In the study it is argued that the design of task is important and, consequently, that the technology *per se* is not determining the effectiveness of the learning environment. The result of our study corroborates the finding of Bernhard (2003) that differences in learning cannot only be attributed to the technology in use who states:

The result of this study shows that MBL doesn't automatically give good learning results. MBL-technology, and other forms of computer aided learning, cannot be implemented as only a technology. The educational implementation is of crucial importance and hence there is no definite answer to the common question if computers help to achieve "better" learning. Another conclusion is that we ... must [be] aware of instructor's conceptions of teaching and learning ...

The importance of taking instructors conceptions into account relates to the point made by McCutcheon (1982) that curriculum matters are strongly related to questions of values:

For this reason, we must understand ourselves – our beliefs about what *constitutes good schooling* and a *just society, how people should be treated*, the role of the good citizen, and so forth. (My italics)

Cherryholmes (1988) points out the close relation between curriculum and the questions of power in the relational sense of Foucault (e.g., 1980; Hall, 2001). We therefore must become aware of our values and question our aims in a course: Are we selecting students with similarities to ourselves or are we giving all students an opportunity to learn? Thus we have to look carefully, at which discourse-practises learning environments favours and disfavours and critically question if the function of learning environment – are students filtered out or is diversity promoted by enhancing the learning of all students (cf., Steen, 1988; Seymour & Hewitt, 1997)?

I argue that the concept of educational accessibility is a "democratic" and enabling concept since it, in our definition, turns our awareness to the design of educational settings and from characteristics of individuals. Designing is always related to values. The concept of "universal design" (e.g. Do-It, no date; Rose, Meyer & Hitchcock, 2005) emphasize that designs from the beginning should be designed with the diversity among users in mind eliminating, or reducing, the need for adaptations or specialised design afterwards. It is mentioned above that it has been argued that MBL should be good for students with disabilities. This is in line with for example Mastropieri, Scruggs and Magnusen (1999) and Mastropieri and Scruggs (1992) who have reported that students with disabilities learned more when taught with an activities-based science curriculum.

I claim that the concept of educational accessibility and the goal of giving all students an opportunity for learning should be natural for teachers. However the hidden curricula have in many cases been the opposite: Teachers could see themselves as "gatekeepers" who function as a filter and select the "good" students. This filtering process is often rhetorically hidden behind arguments such as keeping "quality" and keeping "standards". See for example discussions in Steen (1988), Tobias (1990), Seymour & Hewitt (1997), Schenker & Bernhard (2006) and Bernhard & Schenker (2006). However in our data we could see the opposite (cf., Seymour & Hewitt, 1997) – learning environments that are "good" for female students (cf. Laws, Rosborough & Poodry, 1995) and students with low pre-test scores seem to be "good" for most students. Studies about "universal design" have similar results and for example Rose, Meyer & Hitchcock (2005) reports "[d]esigns that increase accessibility ... tend to yield benefits that make everyone's experience better".

As mentioned above studies of different innovative curricula in physics and achieved learning typically only report averages as results. The implication of this tradition is not a "neutral" reporting, rather it is part of a discourse there young male students are seen as representing "normality". Female students, students from different minority groups, students from families without academic traditions and others are in practice marginalised and thus made "invisible" (Smith & Erevelles, 2004) or "counted out" (Walkerdine, 1998). Rather we have to see diversity and differences as something

natural in human population. We have to shift from a minoritising discourse, seeing so-called minorities as having some “deficit”, to an enabling discourse.

In a forthcoming paper I will further develop the concept of educational accessibility and elaborate this concept in relation to theories for learning, and in relation to the design of artifacts and tasks. In future studies we plan analysing video-recordings to do a fine-grained interaction analysis how a diverse student population interact and learn in interactive learning environments. We will analyse on how the learning environment, in an authentic setting, constitute student course of action and relate it to how learning of physics is enabled for a diverse student body and how diversity is promoted.

The question in the title of this paper was if physics learning environments could promote diversity or if students were marginalised? This papers show that there is no simple answer to this question and the answer lies in the design of the environment and the values embodied in the design. However an important conclusion from this study is that it is possible to design learning environments with high learning gains for most student and that the goals of equity and promoting diversity is not contradictory to striving for excellence. Thus I uphold, as a closing argument, that it is our duty as teachers of physics to design our courses so that the educational accessibility is increased in our courses to enhance the knowledge of physics in society and promote pluralism and diversity.

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