Can We Assess Efficiency and Innovation in Transfer?

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Abstract. Schwartz, Bransford and Sears [1] propose a two-dimensional framework that describes transfer in terms of efficiency and innovation. Efficiency is the ability to apply prior knowledge to new situations quickly and accurately. Innovation is the ability to question assumptions, let go of prior knowledge and generate new ideas. Schwartz *et. al.* argue that most educational assessments focus on efficiency at the expense of innovation. We suggest that this perspective does not adequately reflect the challenges that our students face while problem solving. For instance, while faculty may find end-of-chapter physics problems to be routine and overly focused on efficiency, our students, who lack prior knowledge and experience may find these problems to be novel and innovative. We propose a framework based on an operational meaning of 'efficiency' and 'innovation' and development of criteria to measure these constructs in ways that reflect both learners' challenges as well as educators' expectations.

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INTRODUCTION

Transfer of learning is often considered the ultimate goal of education [2]. Thus, STEM educators emphasize problem solving skills that enable learners to transfer their knowledge productively to new situations. The perspectives on transfer of learning have changed over the years [3]. The traditional meaning of transfer implied the application of well constructed prior knowledge in new situations. Recently, researchers have redefined transfer as the process in which learners construct or reconstruct knowledge in the new situation [e.g. 4].

The purpose of this paper is to begin a discussion in the community on how some views of transfer may be operationalized and how they can possibly inform assessment. This paper will present the beginnings of framework toward this end and discuss the possible implications of this framework. This paper does not present data in support of this proposal. Rather it simply presents the rudimentary ideas that underpin what the author believes to be a possibly useful way to think about assessment of learning.

CONSOLIDATING MODELS OF TRANSFER

There have been attempts to consolidate the traditional and contemporary perspectives on transfer of learning [5]. Indeed, they both have an important role to play in education of our students. In this vein, Schwartz *et. al.* have provided specific guidance [1].

Efficiency in Transfer

Schwartz *et. al* point out that the traditional view of transfer focuses on efficiency [1]. Efficiency is the ability to apply well constructed prior knowledge to new situations quickly and productively. Situations that lend themselves to efficiency are problems that require the learner to recall prior previously learned knowledge in a new situation. Examples of problems that focus on efficiency are some of the easier problems at the end of the chapters in introductory physics textbooks. These problems typically require plugging values into a single equation to find the unknown. The known and unknown quantities are clearly defined in the problem and the process of finding the unknown is obvious to any learner who has minimal familiarity with the formulae. For instance finding the acceleration of a block given its mass and a single force that acts on it, is an example of a problem that focuses on efficiency.

Innovation in Transfer

Schwartz *et. al* describe a second dimension to transfer – innovation [1]. Unlike efficiency that focuses on using prior knowledge, innovation focuses on letting go or moving past prior knowledge and in fact constructing new knowledge – thinking outside the box to solve the problem. Innovation is consistent with the contemporary views that transfer is a process of constructing or reconstructing knowledge to attend to a new situation.

Situations that require innovation are those in which existing models or solution strategies are unavailable or unproductive. Problems at the cutting edge of physics research are good examples of problems that require a high degree of innovation. Problems that are unstructured or ill-structured, where there are no clear starting points or goal states and where multiple solutions are possible depending upon the assumptions made by the learner are all examples of problems that require innovation. Context rich problems are good examples of problems that require some degree of innovation.

Combining 'Efficiency' and 'Innovation'

Schwartz *et. al.* have created a two-dimensional framework show in Fig. 1 that represents 'efficiency' and 'innovation' on two orthogonal axes [1].

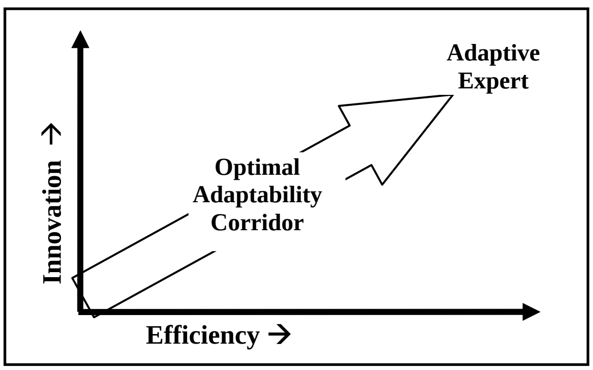

FIGURE 1. Schwartz *et. al.* framework for transfer includes the 'efficiency' and 'innovation' dimensions.

They point out that we must aim to prepare our students to become both efficient and innovative, i.e. learners must become adaptive experts. They recommend the kinds of strategies that can enable learners to develop adaptive expertise. These strategies together enable a leaner to navigate a trajectory of development toward adaptive expertise called the 'optimal adaptability corridor.'

This paper focuses specifically on the implications of this framework on assessment of transfer of learning.

ASSESSMENT OF TRANSFER

Schwartz *et. al.* point out that traditional assessment often focuses almost exclusively on efficiency to the detriment of innovation [1]. While in agreement with this general point, it is also believed that this view is primarily an expert-centered view of our current assessment.

The point is that while some of our assessment in physics might appear to be testing only efficiency from the point of view of an expert, to a novice learner, it probably involves some level of innovation. For instance, when students have not previously seen a kinematics problem which involves more than one equation, are given such a problem, to those students, it appears to be 'innovative'.

Thus, from a perspective that involves the views of both the novice learner and the expert educator, almost every problem can be characterized as involving both efficiency and innovation to varying degrees. The question which then arises is whether we can 'tease out' those two components – efficiency and innovation from any piece of assessment.

Assessing Efficiency

Efficiency is a measure of how quickly and accurately a learner is able to activate productive prior knowledge to accomplish the task. Therefore given an assessment task I have a list of questions that can help gauge the extent to which a task assesses 'efficiency' of transfer.

- To what extent does the task involve a single idea or concept?
- To what extent does the task provide all needed information to accomplish it?
- To what extent does the task provide information in a representation that the learner can directly use?
- To what extent has the learner completed this task before or one very similar to it that she can recall?
- To what extent can the learner complete the task quickly and accurately by following a recipe?

The list above is clearly not exhaustive, but it does provide a sense of issues that are relevant to efficiency.

Assessing Innovation

Innovation is the ability to let go of prior conceptions, reevaluate the situation and construct novel solutions if needed. As shown above I list questions that can help gauge the extent to which a task assesses 'innovation' of transfer.

- To what extent does the task require the learner to combine ideas and information from different sources?
- To what extent does the task require the learner to take apart and re-examine previously learned concepts?

- To what extent does the task require the learner to create new ideas she may not have thought about before?
- To what extent does the task require the learner to reflect on his/her learning?
- To what extent is the task completely novel to the learner?

Again, the list above is clearly not exhaustive, but it does provide a sense of issues that are relevant to innovation.

RELATION TO TRADITIONAL ASSESSSMENT

The point of this paper is not to suggest that we completely change the ways in which we assess student learning in physics. Rather the point is to propose a framework for assessment that would provide a lens by which we can view what we already do and perhaps provide another way to reflect on the assessments that we create.

While it may appear at first glance that typical end of chapter physics problems focus only on efficiency, I argue that this is not completely true. For example some physics problems require learners to combine more than one equation to solve the problem, such as a problem on Newton's II Law where kinematical information is provided rather than a value of acceleration. Others may require students to derive new relationships, such as a problem in the chapter on simple harmonic motion where they are given a new physical system and required to show that it executes SHM and derive an expression for its frequency. Yet another is a problem in electric circuits that has an infinite ladder of resistors that requires learners to recognize the repeating nature of the circuit and use their ideas of mathematical sequences to solve the problem. All of these are examples of problems we might find in physics textbooks but they do have some elements of innovation embedded in them.

TOWARD DEVELOPING A RUBRIC

It is believed that no useful purpose is served by pitting efficiency as being antithetical to innovation. Rather the author is in agreement with Schwartz *et. al.* that we must facilitate our learners to become adaptive experts that are both efficient and innovative. Therefore, in looking at an item of assessment it is not appropriate to ask – does this assess efficiency *or* innovation? Rather, one must ask to what extent does the item assess efficiency *and* to what extent does it assess innovation, because the two are not mutually exclusive.

As demonstrated above some end of chapter problems in introductory physics textbooks have elements of innovation embedded in them. The question above cannot be answered in a vacuum by educators or education researchers. Indeed, to find the extent to which a problem measures efficiency and innovation one should ask not just the educators, but also the leaner that is expected to solve the problem.

Input from Educators

The teacher often has the responsibility to set learning objectives, design instructional experiences and assessment in a class. They also have a sense of the prior knowledge their students have and the typical challenges they might face. Thus a teacher, especially a teacher who has the requisite pedagogical content knowledge, can provide useful input in deciding the extent to which an assessment task measures efficiency and innovation for their students.

To develop criteria based on input from educators, one can present a list of possible assessment items to the instructor and ask them a list of questions, similar to the ones listed in the section on 'Assessing Efficiency' and 'Assessing Innovation'. The response to each question is provided on a 0-5 Likert Scale. By combining the Likert Scale ratings for all of these questions we can arrive at an 'efficiency' score of the problem and similarly an 'innovation' score for the problem. It is important to point out that the efficiency score is calculated from a different set of questions as the innovation score, so they are not mutually related.

Input from Learners

An important feature of this framework is that rating a question on the 'efficiency' and 'innovation' scales depends not only on the input of educators, but also on the input from learners. A learner-centered perspective is especially important because educators may not have a good sense of how the level of efficiency and innovation may be perceived by a learner. A learner without adequate prior knowledge may find a problem that is deemed to be rather low on innovation by the instructor to be rather high on the innovation scale, because he/she does not possess the conceptual or procedural knowledge expected by the instructor.

I believe that an appropriate strategy to gauge the level of efficiency and innovation needed to solve a problem from students' perspective is to observe students working on the problem. By conducting individual teaching/learning interviews it is possible to find out the kinds of scaffolding that a student needed to solve a problem [6]. That information as well as the

Likert scale scores on questions listed in the earlier section on 'Assessing Efficiency' and 'Assessing Innovation' can together provide an efficiency and innovation score on a 0-5 scale for each assessment task.

Combining Efficiency and Innovation

By combining the 'efficiency' and 'innovation' scores on each question on a 0-5 scale, it is possible to position each assessment task on a two-dimensional graph as shown in Fig 2.

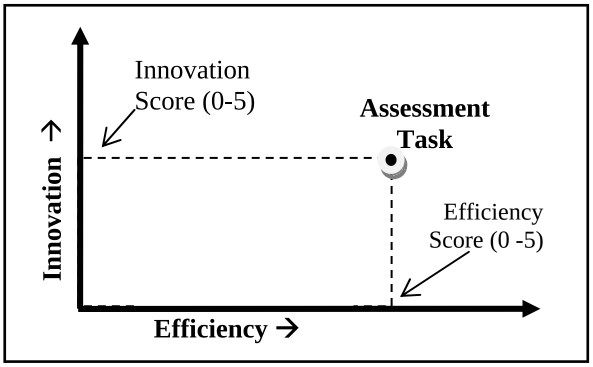

FIGURE 2. Locating an assessment task on the two-dimensional continuum by Schwartz. [1].

If we plot each assessment given in a course on this two-dimensional grid as shown above, then a course where the assessments are balanced across both efficiency and innovation dimensions will have marks that are evenly spread out across the graph. By combining several assessment tasks and their relative weight over an entire course, it is possible to find a given point on the graph above that characterizes the complete course. As expected, a course that balances efficiency and innovation will have this point lying somewhere along the diagonal on the graph, i.e. within an optimal adaptability corridor.

SUMMARY AND IMPLICATIONS

We have proposed a framework for assessment of student learning that operationalizes the ideas of efficiency and innovation in transfer that were proposed by Schwartz *et. al*. [1]. These ideas consolidate the traditional and contemporary views of transfer. Until now there have been no concrete attempts to assess transfer based on these ideas. I believe that this framework is an important step in that direction.

The development of a rubric that enables instructors and assessment designers to operationalize and measure the level of efficiency and innovation in the assessments that they use or design is an important step in that it allows theses stakeholders to engage in reflection about the assessments that they design and also design assessments that are more balanced across the courses. The use of such assessments can also drive the development of instructional strategies aimed at fostering both efficiency and innovation in learning.

LIMITATIONS OF FRAMEWORK

It is also important to point out the limitations in the framework that is proposed. First the validity and reliability of the questions posed to teachers and learners designed to gauge the efficiency and innovation score for any assessment item must be ensured. The same applies to the data collected from the teaching/learning interviews that would provide input from the learners' perspective. Second, the process of gauging the level of efficiency and innovation embedded in an assessment item is dependent upon the characteristics of the learners it is aimed at. It would be time consuming to repeat the process in each context that the assessment is being used. Finally, the level of efficiency and innovation gauged by an assessment varies with time even with the same group of learners. When learners' prior knowledge increases, what they deem to be innovative at one point in time, may not necessarily be innovative later. Thus, this kind of rubric is not easily amenable to pre-post testing. In spite of these limitations it is believed that the framework described here is a necessary first step in highlighting the issues of assessing efficiency and innovation in transfer.

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