Interdisciplinary Approach in Physics Education Using Modeling of Physical Processes

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Abstract. For a long time, many people have been having difficulties with effective learning and deep understanding of various sciences, especially such fundamental one as physics. This is a big problem as it directly affects the ability of humanity to progress, make serious life decisions, improve livelihood etc. This issue was regarded multiple times throughout the history of the human kind, but it all was of little productivity. The reason is that education is a neurobiological process and should be treated respectively. Any investigations that were not using and mentioning neuroscience could not provide precise problem description and solution. The purpose of this article is to suggest a neuroscientifically explained way to make studying and understanding of different matters easier for learners of any age by combining multiple spheres of experience (disciplines) and propose an ICT application – modelling of physical processes – based on the example of physics education. The method, overall, helps the brain improve memory, structurization and merging processes; collect more basic ideas, methods, approaches, real and abstract experience. All of these are the core of creativity, flexibility, inventiveness, problem-solving and deep comprehending, not only in physics, but also in many other fields of human life. Modelling of physical processes might greatly increase the effectiveness of the method and facilitate the learning process.

Keywords: Cognitive Science, Interdisciplinary Approach, Modeling of Physical Processes, Physics Education.

1 Introduction

Learning processes are still not entirely understood. However, relatively recently, a lot of neuroscientific research has been done, which might play a crucial role in making education more efficient. The purpose of this work is to review studies that support the efficiency of interdisciplinary approach in studying and suggest possible ways of implementing it in physics education with the use of modeling of physical processes.

2 Methods

The main source of evidence is the National Center for Biotechnology Information. Some directly related to education works have been reviewed, but the basis of the study and support comes from the neurobiological research. The former give the overall idea of the interdisciplinary approach, and examples of application. The latter allow to understand it more deeply.

2.1 Neurobiological research

One of the core neuroscientific concepts behind interdisciplinary approach is integration of memory. The reviewed studies suggest that this process might be divided into two stages. The first one is when our brain works mostly with novel information and experience [1,2]. During this stage, according to experiments, the sensory-motor system is highly engaged, and the brain mostly works with direct experience of objects. During the second stage, which corresponds to working with rather usual environment, semantic memory plays the important role [3]. Semantic memory operates with meanings and words rather than episodes and objects. Magnetic resonance imaging shows that both stages involve similar regions responsible for analyzing and memory. The main link between these two stages is that when a scene is first encountered it is thoroughly captured and analyzed by the means of the sensory-motor system, then all the details are overlapped with retrieved memory [4]. In such process, information about new experience is being remembered and categorized. Also, each time a memory is renewed, even deeper neural patterns are made, which indicate connections to other related experiences. So, when it's reactivated, it is not needed to fully recover it, instead we can just operate with less detailed information – meanings and words. Because both stages involve prefrontal cortex, it's been shown that conscious thinking and concentration help retrieve memory faster, more productively and sort out more important details of a complex picture. That means that conscious approach to studying promotes comprehension and memorization of the subject.

2.2 Research in education

The importance of real and discrete experience was shown in the study on mathematics education [5]. Learners are more likely to understand and memorize a topic if they can find correlations in various everyday life experience – finances, physics, biology, sociology etc., which also leads to increase in creativity and problem solving. Sources suggest that this is one of the basic concepts of the approach, along with conceptual knowledge, but of the same diversity [6-8].

3 Results

3.1 The efficiency of the method

Learning is a process about not only remembering information, but also being able to generate new one, predicting future situations. It can be drawn from the evidence that learning highly depends on experience. Each novelty requires deep analysis and association to be effectively memorized and understood. Logically, the more different experience we have, the more likely we are to find a lot of associations to a new episode. Other than that, more various experience indicates more available neural patterns for connection. That means that new information can be sorted out quicker if a similar process took place earlier. The semantics part of learning works very similarly. Words or abstractions can have different meanings and when presented novel experience our brain can find associations quicker if there are already existing terms that might fit. Eventually, new experience binds to either a concrete event or a meaning (that chain must end up with a simple record from the sensory-motor system). So, any learning situation involves association to previous experience, and it is not clear how exactly these associations are prioritized, and connections are made, since it all happens on the neural level. But given the current understanding of these processes, their efficiency certainly depends on the variety of existing experience. This is the basic idea of interdisciplinary approach.

3.2 General application

The general concept is that if a learner consciously approaches the idea of creating a learning environment without too much discrimination between events or knowledge it will be possible to easily study and have interest for any subject. Conscious understanding and seeking similarities between different spheres of interest can create more associations and potential connections for future situations. Completely new information, which usually has very few links to existing knowledge, can be more easily perceived with flexible memory (both sensory and semantic), which means open perception, creating rather unusual links in situations event-meaning, meaning-event, event-event, meaning-meaning that are based not on the traditional labeling and common sense, but rather contextual similarities. For example, it is easier to understand the logic of mathematics from the perspective of neuroscience. Since it's usually perceived as rather philosophical and intuitive question, it is not as easily understood as it is applied, because it was created unconsciously. Now, human thinking was thoroughly studied and, although it is yet to be discovered, some major theories have been brought up, backed up with multiple observations. Thus, we can suppose that the logic of mathematics comes from the natural concept of semantic memory. If a person is familiar with that concept, then it will be much easier to understand and even predict some results in that field. It can be math education or anything that relates to its application.

3.3 Application in physics education using modeling of physical processes

Interdisciplinary approach in physics education shouldn't differ from the general approach, but the ways of applying it might vary. Indeed, physical processes take place nearly in any advanced discipline. Physics also benefits from connections to other spheres. Biology, chemistry, geography, economics, even art, mathematics and psychology can bring useful ideas or problems to physics. Besides, every person comes into curriculum with their own set of divergent experience. Being able to connect physics to any other subject or even life episodes can provide not only enough interest, but also facilitate the learning process. Overlapping terms, meanings and words can extend their individual comprehension, making the retrieval faster. The interdisciplinarity between physics, math and programming is specifically important. Combining them together one can model a physical process. It is important because it involves both semantic operating and imaging. When trying to associate a physical event with the semantics of mathematics and programming deep analysis takes place. Both programming and mathematical operations can be applied to any situation and they can be an extra link between physics and other disciplines. So, when figuring out how to effectively create a model, any existing methods can help (which comes down to previous experience). Another point is that, basically, any physical process from another field can be managed the same way, but it would require some extra experience, which can facilitate the overall perception, motivation and memorizing. Other than that, a live model that learners can control by changing parameters makes studying more sensory and intuitional. The analogy can be drawn from small physical experiments, but programming these experiments is easier to establish, finance and make more visual (adding different visual effects or when modeling small-scale processes, like nanowires) [9].

4 Conclusions

Although a lot of neurobiological and educational research suggest that interdisciplinary approach might be very effective in educational institutions and personal development, it lacks direct experimental data and evidence. That would require further study of the subject along the existing educational systems and planning relevant experiments. Nevertheless, some aspects of it has been already applied. It is possible to slowly extend them, given the underlying mechanisms. The main propositions would be promoting scientific open-mindedness and literacy, including more real and discrete learning experience into curriculum, teaching learners the basics of cognitive science so that they can individually control the efficiency of their studying, approaching it more consciously. Modeling of physical processes can facilitate application of the method, although it would require future studies on how to do it appropriately.

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