Engineering the Correlation of Scientific and Educational Systems

Arash Rastegar(Sharif University of Technology, Tehran, Iran)

We construct mathematical models for research in science and evolution of educational systems and then try to understand the correlation between science and educational systems using these models. We have chosen the language of "Atlas of Concepts". This notion has been used before as a mathematical model for mathematical communication. It provides an appropriate tool for understanding of science and educational systems in a common framework. The main question is the following: How is it possible, to guide scientific research via control of educational systems and vice versa, by engineering their correlation? We are particularly interested in the correlation of research in mathematics and evolution of mathematical educational systems.

Models and Analogy

In formal logic, we construct "Logical Models" which are concerned about axioms and their logical relations, or we use models for interpretation of a set of axioms and theorems. These notions are very different from traditional ways of using models in basic sciences. "Analogy Machines" are closer to the real life meaning of the models than the logical one. These models are used for explanations and clarifications in basic sciences and sometimes they are used as scaling models. A few important examples are wind tunnels, hydraulic models for economical systems, electrical network models for neuronal networks. Part of "Analogy machines" are approximating the truth only in the sense that they provide an "Isomorphic" system, and part of them go even further in making analogy in the sense that they investigate in the same language as the truth is, like the wind tunnels. "Mathematical models" on the other hand, do not provide an isomorphic system, but the logical meaning of the models makes their application truthful. For example, probabilistic models are used in the psychological theory of learning, and in dynamics of population. "Simplifying Models" are the most important models used in applied sciences. We can not use them in theoretical sciences. Old models left from refuted theories could be considered as "Simplifying Models". For example, fluid models for heat or psychology of forces. "Theoretical Models" contrary to "Simplifying Models", are the milestones of the future theories. For example, models for DNA molecule or models for universe have lead scientists to develop scientific theories.

In this paper, "Mathematical modeling" is a tool to develop an applied science, which is aimed for engineering the correlation of different branches of science. From this perspective, “Mathematical modeling” could be regarded as a “Simplifying model”. On the other hand, “Mathematical Modeling” is trying to hold an isomorphism between models and truth only from an applied point of view. So we can think of these models as “Analogy Machines”. We intend to build theories on our models, which will make these models as “theoretical models”. Our approach to “Mathematical Models” will have nothing to do with axioms and theorems and any concept related to “Logical Models”. It is the algorithmic nature of our models, which made us regard our modeling to be mathematical.

Mathematical Modeling of Branches of Science

This research has grown out of a new perspective to knowledge, which tries to treat humanities (e.g. mathematics education) and basic sciences (e.g. research in mathematics) by the same methods of understanding. In order to have a rigorously defined relationship between different branches in humanities and between humanities and basic sciences, the traditional way of treating humanities as a big puzzle in which scientists are trying to match their local information to get a global picture, will no longer work. Nor will the mathematical method of forcing randomness and analyzing data give such a global picture of human sciences. Only rigorous understanding of the aims and tools of each of the branches of human sciences can provide us with explicit knowledge of their relationship. We use mathematical modeling for better understanding of different branches of science. We could have many models for a single branch of science, each for the purpose of answering a particular question. One could improve a model, to provide a more delicate system for a better analysis of the particular question toward which our model is aimed for. To have a rigorously understood relationship between two branches of science with regard to a particular question, one should provide mathematical models for both of these branches aimed for answering the same question, in such a way that, these models are introduced by the same languages. This common language makes it possible to have an explicit understanding of the relation between these two models.

Atlas of Concepts

The language of “Concepts” is an appropriate language in which we can speak of both, research in science and educational systems. Concepts are central to researchers in science. In fact, research is nothing but a purposeful game of concepts. Also, in the minds of experts in education, concepts play the main role. They want to find appropriate answers to many questions circling around teaching concepts. Before introducing a model for scientific research or educational systems, we shall introduce a mathematical model for communication of concepts.

This becomes possible only by having a good model for the geometry of concepts, which are to be communicated. This model should fit the nature of communication, so that, in our model, concepts can easily commute.

In search for a mathematical model for a mathematical communication, such a model for the geometry of concepts has been introduced [1]. It is called the “Atlas of Concepts”. This notion is a new version of “Concept Map”. It grew out of an algorithmic approach to the question of how concepts commute. This model was able to analyze both personal and social scientific concepts and also their relation and the way they communicate from a person to a group and vice versa. The idea of “Atlas of Concepts” which comparing to “Concept Map” has the extra notion of “Perspectives”, and also algorithms introduced for communication comes from history of basic sciences.

Science and Scientific Concepts

Introducing a model for a branch of science in order to predict the future developments is somehow an impossible task. This problem is analogous to the problem of artificial intelligence. On the other hand, modeling a branch of science for the purpose of understanding the correlation between science and educational systems is a more approachable problem. The model of “Atlas of Concepts” is an appropriate one, provided that a reasonable definition of “Concept” in that particular branch of science is used in this framework.

In mathematics, we define a “Mathematical Concept” to be a concept which its presence has computational implications. In other words, it should either make it possible to compute some concepts in terms of others in a new way, or it shall help us interpret our computations and gain a better understanding of our computational abilities. In better words, in our model of mathematics, the computational implications of a scientific concept, decides if it is a “Mathematical Concept” in our model; i.e. in this model for the science of mathematics we focus on the aspect of “Computation”. For example, in a model for the science of physics our focus could be “Prediction of a natural phenomena”. In chemistry, “Deformation of material substances” can form the milestone of our mathematical model.

We are not in a position to define each of the branches of science in the language of our models.We are particularly interested in the field of mathematics and do not intend to enter the current discussions on the definition of a scientific concept. Keep in mind that the nature of our brain functioning is by far more opportunistic than letting us explicitly define what a concept is.

Educational Systems and Geometry of Concepts

Modeling an educational system in terms of concepts and their geometry of relations is a tedious task. Because, an educational system, is supposed to educate human beings. So in the process of formation of an educational system, we shall pay attention to all the aspects of humanity. In short, the simplest system analogous to an educational system is human being; which is quite complicated. Speaking of human being in the language of "Atlas of Concepts" would be a task of enormous complexity. The most unnatural aspect is the fact that, here, we try to introduce a discrete model with discrete evolution for an alive being with continuous evolution. We can recover this loss, if the process of formation of the educational system is a continuous coherent process. This continuity somehow overcomes the problem.

We approach the problem of defining the educational system in terms of "Atlas of Concepts" by trying to translate different aspects of human being to the language of concepts. Some of these aspects are related to the creation of the educational system, and some about its relation with environment and some others are related to its individual character and others about communication of the system with other educational systems.

A.Formation of an educational system.

For an educational system to work, many problems should be taken care of. Also there are a number of considerations, which are forced by the analogy between human being and the educational system. The horizontal and vertical links are examples of structures essential for the system to work. Growth of concepts is an example of structures, which should be present to fulfil the analogy between human and the system.

B.Environment affecting the educational system.

Culture and society affect the ways in which an educational system works. Even the geography of the area has serious effects on the material with which the students become familiar with and bring to class from the outside environment. This background knowledge and environmental effects should be considered by creators of the educational system during the formation of the system. An example would be elementary culture of counting which students already know entering the elementary school. Cultural background of students helps educators to teach elementary mathematics much more effectively.

C.Personality of the educational system.

Every purposeful educational system, in order to move towards the goals of the system, emphasizes on certain human characters. These characteristics form the personality of the system. For example, mathematics education emphasizes on certain characteristics in students in order to make good problem solvers. A few of these would be making plans for everything they want to do; reviewing what they have already done in order to criticize themselves; applying the method of trial and error in discovery; and so on.

D.Relation with other educational systems.

Analogy between human beings and educational systems implies that two educational systems relate according to their personalities. More precisely, two educational systems affect each other only when they relate on certain human characteristics or skills which are emphasized by both of them. In better words, educational systems relate only in the practical level. They can not have any affect on each other in the theoretical level. For example, different strategies introduced in different educational systems for the skill of "planning before action" could affect each other. But if this skill is not emphasized in an educational system, it can not be created by other systems.

Now that we have characterized the aspects in which we shall define an educational system in terms of geometry of concepts, we can go one step further and translate each of these to the language of concepts.

A.Concepts and formation of an educational system.

In the language of "Atlas of Concepts", horizontal links are introduced by relation between concepts in each map. Of course, horizontal links can be thought of in different levels. For example, links between concepts in each subject, and links between different subjects are two different interpretations of horizontal links. For each of these levels one shall introduce an "Atlas of Concepts". Vertical links are taken care in the relation of each map with consecutive maps in the atlas. Growth of concepts can be treated in consecutive perspectives for which, the relation between concepts in each map are introduced.

B.Concepts and environment.

Environmental effects also can be understood in the language of concepts. Research based "Atlas of Concepts" for background knowledge of students can be arranged. Also cultural "Atlas of Concepts" for students of different age could become accessible to creators of an educational system. Also an atlas of skills shall be designed by the experts as a goal for the geometry of skills which the student is aimed to obtain to have a happy and fruitful life in the society.

C.Personality in terms of concepts.

Personality of the educational system is a local notion. One shall emphasize on certain local personal characteristics of students to ensure successful performance of the "Atlas of Concepts" as a tool for implying the system. More exactly, for the birth of concepts to happen, there is a need for certain background basic skills, which provide the appropriate human atmosphere for the implication of the system. This brings up the notion of "Atlas of Skills" which forms a tree with exceeding number of branches. The new formed skills make the ground for maps of concepts with new perspectives to be formed. Each skill is a certain union of pre-skills, which can be recognized only by field study. The pre-skills demonstrate different possible levels of sophistication by students. These differences are the milestone of theoretical background for formation of the educational system. So, field study precedes formation of theoretical bases of an educational system.

D.Conceptual correlation of educational systems.

Educational systems socialize according to their personalities. So the correlation of educational systems is characterized by their “Atlas of Skills”. It is not true that common concepts are the basic ground for correlation of educational systems. In fact, the intersection of two “Atlas of Skills” form the common ground for communication of two educational systems. Although theoretical bases of the two systems, affected by their “Atlas of Skills”, can communicate in the language of concepts. Formation of new concepts in the same skill environment, is a result of this communication. We consider the main outcome of an educational system to be the target “Atlas of Skills”.

Scientific Research and Geometry of Concepts

Contrary to the case of an educational system, introducing a mathematical model in the language of concepts for scientific research is not that difficult a task. The reason is the fact that, in an educational system, we are dealing with a continuously changing system, but in mathematical modeling of research in science we are interested in the already existing knowledge. We are not interested in mathematical modeling of scientific revolutions which would be the analogue of creativity in human being. Otherwise, we have faced ourselves with the problem of artificial intelligence which is too difficult to handle. Therefore, the object we are trying to approximate with a model is a static one, thanks to the fact that scientific revolutions do not happen everyday.

On the other hand, mathematical modeling of scientific research is somehow simmilar to the mathematical modeling of an educational system. Because, both of these systems are analogous to human being. Although the analogy between scientific research and human being is partial. To have the full analogy we shall bring in the applied aspects of sciences which we are not interested in, at this moment. In short, scientific research is analogous to human thinking and scientific research minus scientific revolutions is analogous to human thinking minus system changing creativity.

We will use both “Atlas of Concepts” and “Atlas of Skills” in order to give a mathematical model for a branch of science. This way we have taken both pure and applied aspects of a branch of science into consideration. The new notion of “Atlas of Skills” makes mathematical modeling of scientific research more accessible. Each map in the “Atlas of Concepts”, if considered with a different perspective, in a different environments of skills, is prepared to give birth to new concepts in a different manner. Most of the time this leads to new ways which the system could give birth to other concepts in the system. But rarely happens that the born concepts are new to the system. Then, if the environment of skills finds social ground, this new concept will be joining the “Atlas of Concepts” of that particular branch of science. Ofcourse, there have been many cases in the history of science, where a new concept do not find a social ground in the environment of skills of scientists. In these cases, the concepts born by these scientists die after the vanishing of their personal scientific life.

What we shall study in more detail is the nature of formation of new skills in the “Atlas of Skills”. The question is how pre-skills join and form new skills. This is a difficult question, since at present, we do not have a definition of pre-skills in hand. We can only predict their existance by field study. This question is the same as the question about the nature of the birth of concepts. In fact, we believe that a certain skill is formed when a person is in need to that particular skill.

Birth of Pre-skills and Formation of Skills

The simmilarity between formation of skills and birth of concepts has the same nature as the simmilarity between language and thought. Language and thought do not have a parallel and independent development. Once in a while, the process of creation in one domain, is dominated by the other domain. It is the same for skills and concepts. It happens that formation of concepts naturally imply formation of skills. These skills could be behaviorial, mental, computational, etc. On the other hand, a practical need could be the motivation for formation of a certain skill from existing pre-skills, and then formation of this new skill can provide the appropriate atmosphere for the birth of a new concept. The mysterious part is the birth of pre-skills. Formation of skills is simmilar to formation of sentences as a tool for communication and pre-skills are the analogues of words. This would imply existance of a social system for the birth of new pre-skills and their multiple role in the formation of a skill. So Pre-skills have a social cultural nature. They are not constant abstract abilities. Personal pre-skills are reconstructed from the pre-skills common in the society. Usually all of their applications and in many occasions their unification in the occasion of formation of a new skill are also immitated from the society. This will bring a new element in our study of the relation between scientific research and educational systems. The new element is the scientific culture. We can never create systematic relations between research in science and development of educational systems, except if we have a good understanding of the cultural capacities of the scientific society we are working with.

The “Science,Education,Culture”-Triangle

Now that we have an appropriate model for scientific research and educational systems, we are in the position to start the process of engineering their correlation. Naturally scientific culture comes into attension in the environment of this correlation. The language of “Atlas of Concepts” and that of ”Atlas of Skills” provide a common framework to think about the three components of this triangle.

To have the big picture in mind, think of the analogy between educational system and human being and also the analogy between scientific research and human thinking. We shall engineer the correlation of human concepts and human skills. This would be analogous to engineering the correlation of mind and language. The language-mind influence is a social influence and the mind-language influence is a personal influence. In the language of educational systems, the skill-concept direction is social and the concept-skill direction is personal. In the language of science, culture-research direction is a social influence and research-culture direction is personal. These two analogy sysetms are also correlated. Both of the concepts and skills are under consideration in the educational system. The relations between concepts and skills can be engineered in an educational system. This will influence the correlation of scientific research and scientific culture in course of time.

The social system of correlation between scientific research and scientific culture also affects the educational system. Direct systematic changes in scientific research and in correlation of scientific research and culture is possible, but not in the cultural realm. Changes implemented in the large scale, on science and culture fluently affects the educational system as a sub-system. The other direcion happens in the course of time, only if systematic changes in the educational system are internalized. If this be the case, after years one shall be able to observe the influence. Direct systematic changes in an educational system in the levels of concepts and skills and also changes in the system of their correlations is possible. This shows that in an educational system, a goal “Atlas of Concepts” shall be under focus together with an “Atlas of Skills”.

Engineering an Educational System

The main focus here is to find the degree in which one has freedom in curriculum and assessment planning in the levels of concepts and skills and also in planning the correlations between these two levels.The “Atlas of Skills” is the heart of an educational system. It is correlated with “Atlas of Concepts”.

The “Atlas of Concpts” as a mathematical model for thinking has freedom in choice of concepts, the order of their appearance, and in the perspectives they are correlated. As words are the heart of correlations between language and mind, pre-skills are the main tool for correlation between concepts and skills. By introducing new concepts, skills and pre-skills one can plan changes in the educational system.

Engineering a Scientific System

The main focus here is to find the degree in which one has freedom in curriculum and assessment planning in universities to affect scientific research and also has freedom in planning the correlations between scientific research and scientific culture.

Scientific research being analogous to the process of thinking can be influenced by scientific culture, which is the analogue of language, only in the social level. So, only international perspectives can influence scientific research. Scientists are analogues of ideas and it is quite impossible to limit them inside the borders of scientific community. The influence on scientific research is forsed by scientists of other scientific communities. By control of this communication of scientists, if possible, one can control changes in scientific research.

Scientific culture can be directly influenced by scientific research. The correlation of reasearch and culture is analogous to the correlation of mind and language. Scientific ideas which find cultural ground are analogues of words and pre-skills. “Scientific Problems” which are analogues of sentences and skills form the heart of the scientific system. The correlation of scientific research and scientific culture can be controled by “Scientific Problems” of the scientific system. This way we can let research influence the scientific culture the way we wish. The “Scientific Problems” are scientific cultural perspectives which affect the way scientific system changes. To form new “Scientific Problems” in order to influence the scientific society one shall plant the corresponding believe system in several scientific institutions so that the scientific society can popularize them in case it finds cultural background. Changes in the educational system can provide the background in long term.

Engineering the Correlation of Scientific and Educational Systems

The scientific system and the educational system are both analogues of human beings. If we had not consider them in the same framework, it would be impossible to understand their correlation. The language of concepts and skills as a model for both of the systems, provides the basic ground for understanding both of them together with their correlations under the same meaning system. In fact, here we are planning the correlation of two human beings, each consisting of mind and language and their correlation systems. Two human beings can communicate only by means of their languages and they can learn about each other’s system of correlations between mind and language, only by the local information they get from their languages. The same is true for scientific research and “Atlas of Concepts” of an educational system.

They can not directly correlate. The correlation of scientific and educational systems is through the “Atlas of Skills” and scientific culture. Since this information is local, the two systems get to know the skills in the interest of the educational system and the particular scientific problems of the scientific system. But they can not see the global geometry of the “Atlas of Skills”. The communication of pre-skills is only in the context of skills and the communication of scientific ideas is only in the context of scientific problems, because their system of communication is analogous to words communicating only in the context of sentences. So, we shall concentrate on the local communication of skills and scientific problems as the only aspect of communication between the two systems that we can control.

The communication of Scientific Skills and Scientific Problems

By scientific skills we mean scientific practices which find cultural ground, and by scientific problems we mean research questions which find social ground. Reasearch questions are trivially related to scientific skills. Society’s research questions are posed in the language of skills. What they expect as an answer is the extension of skills or formation of new skills which find cultural ground. On the other hand, these new skills provide a more mature language in which the research questions could be posed.

The ultimate tool capable of the control of this correlation is technology. It can provide the basic ground for formation of new skills which are intentionally directed to have special effects on the scientific research questions. On the other hand, popularization of scientific researsh questions via scientific institutions and government funds can help formation of new skills in the society and therefore affect the educational system. The influence of the former direction is much stronger than the latter. This is why the educational system can affect the scientific system much more seriously.

Now the big question is what the main ingredients of an effective technological movement are to accurately influence scientific skills in the society.

References

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