GoScience and Goerudio projects for encouraging STEM learning.

Romans Vitkovskis, Uldis Heidingers
Latvian Education Foundation

Abstract

Learning STEM is primarily dependent on comprehension, because skills without comprehension have no value. For this reason, a number of consecutive projects were implemented to solve this situation. The Latvian Education Foundation project in Latvia, the EU Goerudio and GoScience projects address learning of STEM based on comprehension without deviating from or altering the national standards of STEM contents. Among other methods, the model method is used to gain comprehension; this promotes reverse thinking, creativity/fantasy and is more efficient to distribute. In this approach, theory is a model of nature, but students also can build a model for the theory that, when created by the students, demonstrates their comprehension and requires high input of creativity. It also substantially transforms the education process by engaging the students. This approach creates a way of teaching to learn new things, because in a short time the rapid progress of science and technology requires the learning of new things rather than vegetating with the knowledge obtained through education.

EU projects, the national project and STEM

Learning STEM is one of the key problems of the education process. There is a high degree of reluctance among students to learn, and there are equal problems with STEM teaching. The key tasks of the Goerudio project were to establish the main reasons for the problem and to discover the methods available form improving STEM learning. As a natural progression of the Goerudio project results, the GoScience project was created.

The Goerudio project revealed that the main barrier for the students was comprehension (no comprehension, therefore no enjoyment), as well lack of methods and methodology encouraging comprehension in the teaching environment. It was found that there are only a few methods specifically aimed at promoting comprehension and some of them are linked to locally available resources and are poorly distributable, such as robotics, etc. The model method was chosen as one of the most promising methods; it is directly relatable to the reverse thinking concept, easily distributable and with established methodology proven over 9 years in Latvia (joint project by the Latvian Education Foundation and EM Metodoloģijas Ltd. in collaboration with the website goerudio.com). The applicability of this approach has been experimentally proven under the Goerudio project by training the teachers who presented working models by students at the final conference.

The essence of the GoScience project.

The GoScience project was created to focus on the main problem of not learning STEM – the comprehension, using the model method as one of the basic components of reverse thinking.

The aim of the project is to develop youth culture of gaining comprehension in science subjects (mathematics, physics, chemistry, biology) as well as to promote students' creativity, thus making scientific knowledge better understandable and with higher probability of implementing it in real life.

For encouraging the fantasy/creativity of students, the GoScience project implements various forms of art. If students are comfortable, they have no dislike against the subject and are ready to discover the related skills, seeing they may be useful at some point. The model creation process itself requires fantasy/creativity, which, together with the comprehension obtained, significantly improve the students' ability to learn or create new things. It is very important that the students intuitively accept that what they have learned is natural or unnatural. Intuitive resistance begins with lack of comprehension, whereas with comprehension everything is in order – I am familiar with this already and everything is how it should be. Comprehension is an intuitive category and is directly linked to comfort or discomfort – a scientist's discomfort is a cause to look for solutions, whereas a student's discomfort causes dislike of the subject. Fantasy/creativity should, of course, be developed additionally, because then students may have less difficulty with creating models.

Model explanation

We provide our explanation for the term "model" used in this publication. When an actor changes the stage for the audience, he becomes a spectator, and conversely, when a spectator is brought onto stage he becomes an actor.

From the user's point of view, a model is an interpretation of formal theory or natural elements in an environment familiar to the individual.

The model answers the question "Why?" contrary to "How?" of the experiment and "How is it observed?" of the example.

The GoScience project uses models in a reverse sense – models of STEM topics in an area familiar to the students – natural processes, domestic activities, etc.

Explanation of the reverse thinking

Reverse thinking, as used in this article, is not only the practice of creating individual models for each STEM topic, but also a practical everyday ability to apply all that is new to familiar things and feel discomfort in case of not succeeding at that soon. In normal cases, a student's failure leads to discomfort and solving it by eliminating the topic, whereas a student trained with models will start looking for a solution to the discomfort. This is the beginning of innovation because in this case the student is placed in the position of a scientist/inventor. By learning such skills, a student can become a highly-demanded university or job applicant.

Use of models.

The Latvian practice (goerudio.com) over 9 years shows that creation of student models for STEM subject topics works. Students are able to present models answering the question "Why?" to theory topics and their created model base allows inventing or discovering the same again. This is an experimental result that is visible in the public space on the www.goerudio.com website supported by the Latvian Education Foundation
, which received the 2011 Latvian Innovations Award in education awarded by the President. If a student has been able to build a correct and convincing STEM topic model, they have understood the topic. The use of reverse models in education under EU Goerudio project was referred as the model method. The GoScience project will educate teachers on using the model method and its methodology.

Comprehension and its role

The model method naturally transforms the learning process from "the teacher speaks and the students listen" to "the students speak and the teacher leads the process", because students not only have to build models, but also have to present them in front of their class. With this, the GoScience project is aimed at significant involvement of students in the learning process itself.
The project outputs will give the teachers the freedom to relate concepts in scientific subjects, which often are situated in different grades in the curricula for students to study, which make students forget and lose the connection between the different knowledge units, which decreases their comprehension and functional literacy and leads to serious underachievement in the science subjects, which also is a reason for students not having the ability to work on development of transversal competences in the future.
As part of the GoScience project, suitable online STEM learning tools will be created according to the principle STEM topic + specialist-proven model, where models will mostly be selected from the most successful models of students, building a learning tool that is maximally approximated to gaining comprehension by the students.

As explained in [1.], creation of new concepts is dependent on the number of new real-life observations and they can be substituted by previous real-life observations that have given stable and permanent concepts and relationships. Thus, models (interpretations to a different area) significantly reduce the time required for building new concepts and relationships. The essence of the learning process – acquiring knowledge is most frequently substituted by memorising information or poor application according to certain patterns (for example, maths).
If knowledge is defined as "information & comprehension", then there is currently abundance of information, whereas comprehension is virtually excluded from the learning process.

Comprehension cannot be discussed without explaining our use of this term – **comprehension is the ability to transfer/interpret theoretical definition of any matter or relationship to another area using a counterpart matter or process from the chosen area – a model.**

Comprehension gives the feeling of comfort that gives an intuitive feeling of the naturality of the matter. Gaining comprehension is a process through which the student obtains the ability to notice natural counterparts in other areas and to apply the theory concepts and relationships to them. Noticing natural counterparts and building interpretation/model requires a creative approach – creation of a new counterpart anecdote, story, video, photo, drawing or caricature. This process is permanent and in many occasions is based on previous creations, as well as complete innovation. Until now, some teachers have used models in their explanations of the subject, but those have mainly been models developed by the teachers themselves (formal interpretation to another area) and often not understood by the students due to age differences. This is one aspect of the topic, however, there are other significant effects that demonstrate the benefits of the comprehension process.

As is widely known, serious exploration of the latest achievements requires thorough knowledge in the specific area, whereas comprehension of key concepts and relationships can provide an insight of "what are is this, what is it based on and what are the latest achievements in it". This would prevent the lack of comprehension among students about various natural sciences, engineering sciences and areas, etc., facilitating further choice of studies not based on any attractive external attributes or recommendations by others. This is one of the currently available constructive ways to deal with information collapse. A list of knowledge and skills required for each area should be added as well.

The existing learning process could be divided into two parts – discovering comprehension/model building, information to be learned and basic skill training to launch at least some attempts at application of the selected information. These could be basic schemes for working with the selected information (theory, instructions, etc.) objects (theory apparatus), assignments, laboratory classes, etc. Taking maths as example, the substance of the maths branch, theory framework and key results may be given at the comprehension level, whereas theorem proving methods, formula inference methods and assignments to practice the application of the methods. Such structure of the learning process would release the students from "believing" in theorems without proof and formulas without inference, as well as demonstrate what theories the current maths is composed of, what are their goals and key results, as well as the naturality of their occurrence. The same applies to physics, chemistry and other subjects. One of the benefits for skill learning motivation is the release from belief against the possibility of constructive ability.

One of the key motivations for a student is the feeling that they can do it if they are trained in the respective area, while not losing the sensation of how it was achieved. This is a natural feeling that serves as motivation, because the awareness of ability gives the sense of comfort and achievement. We reached these conclusions from approximately 40 years of experience delivering lectures and working with winners of science olympiads at summer camps where renown

leading scientists used models to tell students about the latest achievements in their fields and were surprised by the students' comprehension ability. Now many of the olympiad-winning students are world-class scientists thanks to learning to find counterparts in other fields and creating models that are attractive and familiar to them. Most of them won at the olympiads thanks to their ability to apply the existing skills and, to some extent, comprehension, and subsequently became excellent scientists by beginning to rely on comprehension and retaining the awareness that skills permit implementing comprehension-based fantasies (formulation of new things) in theory or experiments.
GoScience is the first project to address the STEM learning problem holistically rather than partially. This results in:

1. Involvement of teachers in application of the model method with respective training.
2. A naturally changed learning process because students need to build the models, present them themselves, while the teachers lead the process and evaluation with discussion.
3. Creation of models by students builds comprehension of the STEM topics and with it the sense of comfort that reduces the resistance against learning STEM topics.
4. Providing a "cheat sheet" using the GoScience online learning tool, showing that models are good and we can create them ourselves.
5. Establishing the difference between model, experiment and example.
6. Providing approach to learn new things – interpreting to familiar things and dismantling the intuitive barrier against all that is unfamiliar and new.
7. Achieving comprehension as the key motivator of the sense of comfort.
8. Accepting the creativity of students and recognising their sense of ability.
9. Enabling unconventional learning using models for comprehension.

Knowledge and their useful duration.

Until not long ago, the knowledge obtained at school and in the university and the related skills remained valid for decades. Now, the knowledge obtained in the study process is usually obsolete and not useful in the labour market. This has been long confirmed by maths – all you learn you can only use as an example or training session and you will have to make your own path into the unexplored. Maths is a special case because everything is valued for innovation and the old achievements are not rated highly. This is an especially creative field with a huge demand for imagination. However, models apply to the basic elements of maths and it can be seen that maths was not invented by aliens. Today's math consists of a multitude of branches and directions, among which even I as a mathematician can only identify the related fields, while the dealings of others are a complete mystery to me. We cannot tell today's students that maths is what it was 400 years ago. This is no longer true. We have to be either able to explain why we are teaching this all or give up and admit that it is all nonsense. Models can provide a lot for comprehension while building a picture of how maths is constructed. Maths cannot be taught by maths amateurs because "drifting" in the subject can

spoil all the understanding of the subject. Unfortunately, education establishments do it by allowing the subject to be taught, for example, by architects who have had maths at a higher level than required at school. They only have functional concept of maths, rather than a holistic understanding. Subsequent "knowledge" is only a myth and useless baggage that may be used for calculating the size of flat. The same applies to learning a number of professional subjects, since all the knowledge has long become obsolete since the beginning of the studies. Therefore, the knowledge obtained in the learning process is useless for practical application. If we consider that knowledge is information & comprehension, this can be fixed by changing the accent in the education process. The education process should involve building comprehension and gaining it by using models that have demonstrated their efficiency, as well as subsequent building of comprehension based on reverse thinking resulting from the model building experience. Thus, education should not give knowledge of certain things, but give knowledge about how to gain new knowledge – teaching to learn.

The GoScience project is a source of creating new desire to learn something new as real achievement of daily comfort situation for each student. Focus of the GoScience project – comprehension is not a magic potion, but rather a sufficient aspect that lets each individual feel comfortable in the existing space. Sense of comfort is a measure of the quality of life and it affects students the most. When a student feels comfortable, there aren't and cannot be any problems with learning of STEM and other subjects. The expiration date of knowledge is erased by new knowledge that overturns, adds to or transforms the previous one. This is a permanent process and we only see its consequences.

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