

M. M. KIRYUKHIN, PhD in Physics and Mathematics, Senior Researcher

SCIENCE LITERACY AND STEM. WHO IS THE BOSS?

Abstract. *Science literacy, science popularization and STEM were analyzed as the structural elements on popular science landscape. Author considers audience, tools and other specific features for each of these elements. Modified definitions are suggested for simplification of further analysis. It was shown that starting from 21st Century science literacy and science popularization can be considered as two separate elements with different objectives and different audience. One more conclusion is the following. Public funding is the mandatory requirement for sustainable development of science literacy. The joint project was proposed for acceleration of World Organization on Science Literacy creation. The essence of this project is to create, print and distribute joint textbook "Create yourself by use your own tale" for increasing children creativity. The book should be adapted to the features of up to 10 countries.*

Keywords: *science literacy, science popularization, STEM (science, technology, engineering, mathematics), definitions.*

INTRODUCTION

The expressions: "science popularization" (SP) and "science literacy" (SL) are relatively new, but activities, which are corresponding to these terms have been known during long times. Physical/scientific experiments in sovereigns' palaces in the Middle Ages are well known from the history. This was the specific format of SP and dissemination of SL at that time. Public experiments with the Leiden Jar [1] and the Magdeburg Hemispheres [2] were used for enlargement of the audience in a later time. The next increasing of the number of ordinary people who are interested in the science achievements was in the twentieth century. First of all, it was triggered by increasing of population general literacy. Another reason is use of scientific achievements in everyday life. Examples: cars (interest to chemistry, thermodynamics, mechanics), telephones (electronics), aviation (aerodynamics, strength of materials). Space has formed one more group of enthusiasts. Above examples can be named as SP, which are increasing SL at the same time. In other words, it was quite difficult to separate these two concepts / elements in the past. But really nobody has needs for such separation: the size of SP/SL "users" as % % of the total population of the Earth was negligible.

Let's return to the present. Almost all population of the Earth has the daily needs in scientific knowledge (science literacy). The majority of the inhabitants of our planet starts their morning from analysis of COVID-19 data. Another examples: information about weather anomalies or air pollution. Let's preliminary name this demand as well as all "additional parts" (audience, tools, etc.) of this element as SL (in 21st Century).

At the same time, the groups of enthusiasts (ordinary people), which want to get extra information about space or biology, don't disappear. These second type of people requires more specific scientific information. It is natural to save SP as the name of this element.

The difference between two groups is more clear in case one uses the analogy with meal. The first type is similar to the daily bread and the second one is the dish from the restaurant. Therefore, author assumes that SP and SL should be separated in the 21st century. Moreover, new element, which is STEM (Science, Technology, Engineering, Mathematics) was added to the original two ones for completion the the overall picture. Each of these elements has its own audience, its own promotion tools, funding sources. Below are the author's definitions for each of the elements, their short descriptions, as well as the arguments for their separation.

SCIENCE POPULARIZATION

Both "ordinary people" and "promoters" consider SP as hobby until the beginning of 20th Century. The main format of popularization was the writing and publication of relevant books. Scientists described the essence of complex scientific phenomena for the ordinary reader. The classic example is M. Faraday's book "The Chemical History of a Candle" [3]. An outstanding scientist of the 19th Century showed the main physical/chemical processes that occur during the burning of a candle, and also their relationship. The novelty of this book is remained even for present.

The above term "ordinary people" defines the audience of "users". This term should be clarified

as following. The audience of “users” of SP consists of “ordinary” readers in the sense that their main profession is not the science. But these “ordinary” readers are not fully ordinary because they have hobby: interest to science.

The increased role of science in the twentieth century initiated the beginning of a systematic approach for its popularization. Scientific achievements began to be popularized not only by the books. Specialized movies were appeared. For example, YouTube became a storage of “light” scientific information in the format of short movies. The National Geographic channel with its excellent programs/movies is another tool of SP.

New step (or even jump) in SP was made at the end of the 20th Century. The creation of popular presentations — PP (films, books, lectures) became the part of significant number of scientific projects. These PPs explain in the language understandable for ordinary people: why do we need the results of this particular scientific project.

Let’s imagine SP until the second half of the twentieth century as certain “amorphous substance”. By use of this analogy, we can say that “microcrystals” (individual PPs) spontaneously appeared from this amorphous substance at the end of the last century. And PP “community” can be named as “big crystal” — absolutely new format inside the traditional science popularization. The term “big crystal” is used because PPs differ from the old tools (amorphous substance) by their structuredness / self-sufficiency. Namely: the own audience (which is still limited), regular and qualified authors and (which is the most important) understandable and sustainable funding. Similar to the crystallization process in nature, our mental “big crystal” was not limited by PP of scientific projects. Similar schemes have been used by industrial companies for popular explanation of complex machine work (with advertising of their own products at the same time). One more part of “big crystal” is popularization of history: new type of movies with participation of both actors and scientists. As to the author’s opinion, the aggregate of listed self-sufficient projects should be named now as “popularization of science” (for 21st Century).

In other words, science popularization is simplification of deep and complicated scientific knowledge (by use special formats), which transforms boring and abstract results into understandable and interesting for wide audience

The author sees the following as confirmation the fact that the modern popularization of science has become a new systemic phenomenon. SP became itself as the subject of scientific research. Good example is the Report on the Development of

National Science Popularization Capacity in China (2006–2016) [4].

We should stress one more positive effect of PP at the end of this chapter. It is evident that PP is the extra tool for inspection of public funding use. From the one side, PP lobbies of the extension of on-going scientific project. At the same time, PP makes this specific project more transparent and supports public inspection of the quality of scientific research.

STEM

Let’s continue the analogy from the previous section. The second “crystal” appeared after the first one from the amorphous substance. Unlike the first case of “spontaneous crystallization”, the second “crystal” is the result of the focused efforts of a group of stakeholders. In 2001, the STEM Alliance was created in the USA [5]. Its main objective is promotion of importance of development of natural science, technology, engineering in the US. At the initial stage STEM day-to-day practice can be used as “etalon” for lobbying. Alliance reports showed that the time between Alliance request and US Senate’s decision is one month or less. The immediate reaction of decisionmakers opens the possibility for creation of efficient system for training of talented young people in the field of natural sciences. Next step was expansion of STEM scheme worldwide. Please, note that the global STEM lost its function as lobbying organization. It has transformed into yet another system for the dissemination of scientific knowledge. One can find STEM training courses everywhere. Similar to the modern popularization of science, STEM is also can be characterized by its structuredness / self-sufficiency. It has its own target audience, teachers and funding sources. The author suggests the following definition for STEM. STEM is the selection of young people with good abilities in natural sciences as further “innovation engines”. Again, like SP, STEM covers a limited part of the world’s population.

The definitions for SP and STEM proposed by the author in chapters 2 and 3 are not new. They are almost the same as the generally accepted ones. The objective of author’s corrections are for underlining the difference between SP, SL and STEM.

SCIENCE LITERACY

Elementary skills in science literacy were easily mastered by the world’s population. For example, most of us learned without external support of how to extract short-term weather forecasts from the Internet.

Unfortunately (or fortunately), science has created and continues to create much more complicated problems. And each individual has to find

his/her own answer. The list of such problems includes, but is not limited by the followings:

- Due to global climate change, huge areas, where millions of people live today may be flooded. Others will turn into deserts. What is about your personal place of living?
- The development of artificial intelligence has already led to the destruction of a number of “routine” professions and this trend will be only continued. Does your position ok?
- COVID-19 has transformed online communications from exotic to routine. Are you inside the trend?
- Space programs of a number of countries are already planning the mass colonization of other planets. Are you ready for such future for your kids?
- Robotization can transfer the conflict between human beings and robots from Si-Fi books/movies into reality. Do you feel the threat?
- Social networks with billions of users are radically changing the way of people communications. Are you ready to eliminate eye-to-eye meetings?

This list can be continued. But one can make the first conclusion even from above. To find the own answers for navigation in the modern world, the minimum of scientific knowledge (MSK) is needed for each person on our planet: for housewife, for businessman, for metallurgist, for farmer. Of course, the content and size of MSK is not a universal constant (like the speed of light) for all inhabitants of the Earth. Obviously, that the required MSK will be different for the people of the different ages and the different educational background. Most likely, it can be different for the population of different countries. Even within each country, MSK will differ from region to region: for example, for urban and rural areas. One should take into account the cultural, religious features of the inhabitants as well as language distribution in the specific and region during determination of MSK.

Fortunately for us, the modern science is not only created the challenges, but is also produced convenient tools. Today one has no needs to visit the library for MSK: everybody has Internet at home. Physical visits to the school or to the university are not necessary: the required consultations can be obtained on-line. Simple software tools allow everyone to formulate conclusions in the friendly format. Based on above, the forming of individual MSK is simplified (or is made more complicated?). Each inhabitant of our planet can create his own MSK independently. The only problem is to be sure that gathered information is not false. Thus, external support is needed for teaching of how to get fair information.

With above remarks, we can suggest the definition for SL. Science Literacy is the “aggregate

of actions and tools” with free access by use of which any human being on our planet can obtain minimum needed portion of fair scientific information to feel himself comfortable in the modern world.

At the end of this chapter, let’s look, what was left in “amorphous substance” after above structuring made by author. Regular SP products (in traditional/old meaning) almost absent in the modern world. The same time masterpieces are appeared on case to case basis. And it is natural, because the masterpiece is always a single case. The last example is the 2021 Oscar-winning movie “My Octopus Teacher” by C. Foster [6].

SOURCES FOR SUFFICIENT SL FUNDING

In the previous sections, the author has made some corrections of the generally accepted definitions of SL, SP and STEM. They were made to emphasize the following.

STEM is state oriented education policy to satisfy specific country needs with limited audience;

The most active part of SP transforms into a chain of business tools for promoting certain types of innovative products.

The rest is SL according to author’s definition. There are two reasons for such classification.

The first one connects with funding scheme and requires some comments. By use business terminology, the STEM clients demand is to get better educational training in selected areas (natural sciences and technology). The request from SP client is to get some sort of entertainment. STEM and SP community provides their clients by required products/services. And can do this job (more or less) efficiently.

The situation with SL clients (in author’s definition) is differ from above. SL clients require (not too much but FAIR) information to make decisions about key human needs. The number of such type of clients exponentially increased at the beginning of the 21st Century. According to author’s definition SL covers all categories of human beings, from kids to Nobel Prize winners, including experts and housewives. And this huge audience of ordinary people is left almost alone with the questions described above because present SL aggregate of actions and tools mainly consists of borrowings from SP and STEM. The nomenclature and quality of such tools couldn’t satisfy even small part of new audience.

One can find the contradiction in the above description. In case author would like to use business terminology, the basic business laws should be worked. In other words: a lot of clients automatically increases the number of suppliers. But it is evident that such statement is not correct for considered case.

We do believe in the absence of the mistake. It is impossible to consider SL as ordinary business:

potential profit is too small at the moment. More likely that SL is the “special type of business”, which was appeared in the middle of the twentieth century. The first examples were: the space and atomic industries. Solar energy, cars with electric engines, private space programs, and even STEM are the examples from the 21st Century. The scheme for any of the above projects was almost the same.

- The size of potential market should be really huge.
- The initial decision is based on the general feasibility of idea.
- Sufficient funding is allocated without deep analysis of existing technological level.
- Project development pulls up science and technology to the profitable level.
- Product is become profitable, and the project is extended worldwide.

The key difference of above business scheme from regular one is sufficient funding based on forecast only. Decisionmakers don't have satisfactory technologies at the moment of funding launch.

There are at least two criteria for application of special business scheme: a) to be the first on the market; b) to have really huge market size.

Structurization of the whole popular science landscape allows to consider “special business scheme” as the most acceptable for SL. This is the first conclusion from above analysis.

Potential institutions, which can provide SL project by funding are: World Bank or other international financial organizations; Belt and Road Initiative; G7 recently announced Global infrastructure project.

Unfortunately, zero stage was missed in above (very optimistic) list of actions. Zero stage is the long period of “knocking into the door” by initiators/enthusiasts.

Appropriate decision about SL as world size project has not been made and is not even discussed. Thus, the enthusiasts are required to explain the role of SL to decision makers. Such enthusiasts have already appeared. Representatives of more than 20 countries became the members of Working Group for the creation of the World Organization for Scientific Literacy (WOSL). Since October 2018, international seminars and meetings have been regularly held, at which members of the working group exchange views and form a common vision of the problem. One can find more information about Working Group activities on the website: https://www.wosl.org.cn/index_en. To be honest, the present progress is impossible without the organizational support of these enthusiasts by China Association of Science and Technology.

Enthusiasts should knock the door more louder for successful start of large scale project. And this is the second conclusion.

The more concrete proposal about the first joint project is in the next chapter.

PRIORITY JOINT PROJECT

The author has previously described the mechanisms for the successful promotion of scientific literacy [7]. The most effective one is the printing and distribution of books. It is clear that the books should be distributed in the countries-members of WOSL Working Group at first. Our proposal is to select modified textbook “Create yourself by use your own tale” for the first joint project [8]. UNISEF funded the creation and printing of the initial version of this textbook in 2003.

This specific choice was preliminary (and very briefly) discussed at the meeting of the WOSL Working Group in March 2021. Present chapter contains detailed arguments to support this variant.

- Why do we suggest exactly this book? First of all, UNISEF label confirms the high quality of this product. Secondly, the book audience is children, which is always the priority. Thirdly, this textbook is the base for successful training of children in Ukraine during last 15 years;
- The formal and the main objective of this textbook is to transfer to children the basic knowledge about methodology of inventions. At the same time, successful completion of the course does not mean that 100 % of students will become inventors in the future. They can be successful scientists or engineers. They also can be successful businessmen, economists or designers in the future. The key word is “successful”. Because the course supports and develops one of the most demanded skill today: CREATIVITY;
- Of course, the first joint SL project cannot be based on the old (20 years old) content. There were no smartphones, no unmanned cars, or detailed plans for the colonization of other planets at the time of writing proposed textbook. So, the primary variant of the book should be upgraded. And the author already started this job;
- It seems, that the new version of book should be structured as the next:

The book should have up to 10 versions prepared for 5–10 countries of members of the WOSL Working Group;

Approximately 70–80 % of the total volume is the general part, written by Dr. Nikolai Turov, the author of the initial book;

The remaining 20–30 % is a variable part, which will be prepared according to the features of each country;

The representatives from appropriate countries of WOSL Working Group should be the co-authors of the variable parts;

It seems that all 5–10 versions of the book will be prepared in English, although the possibility of publication in national languages looks more attractive;

- The main characteristics of the future book should be the following:

The volume of the book is about 100 pages;

It should be printed in color;

It should be (at least) 300 copies for each version/country;

The electronic content as the annexes (may be in local languages for each version).

Creation of proposed textbook will give great push for completion of WOSL.

CONCLUSIONS

1. Structurization of the whole popular science landscape demonstrates element with extremely huge audience, namely, Science Literacy.

2. The quality product, which doesn't exist yet, should be provided to this audience. The core of this product must be the same worldwide with differences according to the age, language, mental-ity, etc. in the regions.

3. The niche is temporary empty. Without delivering of quality product this niche will be filled by electronic game, drugs, etc.

4. Outstanding results of STEM promotion was reached due to regular public funding. Similar scheme should be applied for SL promotion.

5. Initiator of SP extension worldwide is WOSL Working Group. Creation of full size WOSL skids by many reasons at the moment. Thus, WG size should be enlarged for acceleration.

6. Creation, printing and distribution of textbook "Create yourself by use your own tale" is proposed as WOSL primary joint project.

7. The last but is not the least: clear answer on the question in the title. The answer is simple: both elements (similar to two wings) are needed for future progress.

REFERENCES

1. Leyden Jar. *Wikipedia*. Retrieved from: https://en.wikipedia.org/wiki/Leyden_Jar.
2. Magdeburg Hemispheres. *Wikipedia*. Retrieved from: https://en.wikipedia.org/wiki/Magdeburg_hemispheres.
3. Faraday, M. Chemical History of a Candle. *Wikipedia*. Retrieved from: https://en.wikipedia.org/wiki/The_Chemical_History_of_a_Candle.
4. Wang, Kangyou, Yan, Shi, Zheng, Nian and others. Report on the development of the National Science Popularization Capacity in China (2006–2016), China Research Institute for Science Popularization, Beijing, 2017, 148 p.
5. STEM Global Alliance. Retrieved from: <https://www.nyas.org/programs/global-stem-alliance/>.
6. Short description of movie: My Octopus Teacher. Retrieved from: https://en.wikipedia.org/wiki/My_Octopus_Teacher.
7. Kiryukhin, M. (2019). TOP-4 secrets for science literacy promotion, *Science, Technologies, Innovations*. 4, P. 11–15.
8. Turov, M. (2003). Create yourself by use your own tale. Kyiv, 128 p.

М. М. КІРЮХІН, канд. фіз.-мат. наук, с. н. с.

ЗМАГАННЯ НАУКОВОЇ ГРАМОТНОСТІ ТА STEM: ХТО Є ГОЛОВНИМ?

Резюме. У статті наукова грамотність та STEM були проаналізовані як структурні елементи загальної картини з популяризації науки. Автор розглядає аудиторію, інструменти та інші особливості для кожного з цих елементів. З метою спрощення подальшого аналізу були запропоновані модифіковані визначення для цих елементів. Було показано, що, починаючи з XXI ст. наукову грамотність та популяризацію науки можна розглядати як два окремі елементи з різними цілями й аудиторіями. Висловлено думку, що державне фінансування є обов'язковою умовою сталого розвитку напряму "наукова грамотність". Запропоновано спільний проєкт для прискорення створення Світової організації з наукової грамотності, сутність якого полягає в створенні, друку та розповсюдженні спільного підручника "Створи себе через казку", що має на меті сприяти підвищенню дитячої креативності. Заплановано, що підручник буде адаптовано до особливостей приблизно десяти країн світу — членів Робочої групи зі створення Світової організації з наукової грамотності

Ключові слова: наукова грамотність, STEM (наука, технології, інжиніринг, математика), популяризація науки, визначення понять.

INFORMATION ABOUT THE AUTHOR

Kiryukhin M. M. — PhD in Physics and Mathematics, Senior Researcher, President of Union of scientific and engineering societies of Ukraine, Sichovukh Striltsiv Str., 21, Kyiv, Ukraine, 04050; +38 (044) 272-42-85; info@snio.org.ua; ORCID: 0000-0001-6017-4043

ІНФОРМАЦІЯ ПРО АВТОРА

Кірюхін Микола Михайлович — канд. фіз.-мат. наук, с. н. с., президент Співки наукових та інженерних об'єднань України, вул. Січових Стрільців, 21, м. Київ, Україна, 04050; +38 (044) 272-42-85; info@snio.org.ua; ORCID: 0000-0001-6017-4043