University-to-School Environmental Projects for Sustainable Development: A Case of Ural Federal University

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Abstract. Sustainable development is a worldwide recognized social and political goal; it is discussed both in academic and political discourse. According to the authors, the formation of a new way of thinking will help to achieve this goal. A lot of research is related to sustainable development in higher education. However, mental models are formed even more effectively at school age. The paper was written in the context of Russia, where the subject of sustainable development in education is extremely poorly developed. The case of Ural Federal University was presented. The University has been working for several years on the creation of a device for the purification of sewage industrial water in the framework of an initiative student group. Recently, schoolchildren have joined this work. Such projects have been called university-to-school projects. Successful solution of inventive tasks contributes to the formation of mental models. The case has been analyzed in terms of institutionalism. The authors argued the primacy of mental institutions over normative in the process of sustainable society construction.

1. Introduction

There are two polar points of view on what is happening to the climate of our planet. But the proponents of the theory of global warming, and their opponents agree that humanity contributes to climate change. The growth of the world's population and technological progress requires more and more energy, which can only be obtained by burning fuel. As a result, technogenic pollution of the planet only grows from year to year. As a result, air quality in large cities does not meet the standards, which leads to an increase in the incidence of respiratory, cardiovascular, and allergenic diseases. This leads to annual financial losses comparable to the GDP of a small country.

Another problem is the quality of water. The amount of water in nature is almost identical. For use in industry, agriculture and everyday life, mostly fresh water is suitable. Discharge of contaminated water leads to a decrease in the quality of drinking water, thermal pollution of water bodies, and flooding of territories. At present, the demand for water has reached such a level that in many places on the planet, including Europe, there is an acute problem of lack of fresh water. Scientists warn that in one or two generations the majority of the world's population will lack fresh water [1].

Anthropogenic impact on the biosphere of our planet is so global that governments of the world have to cooperate in the field of ecology. But here, everything is not so clear. The desire to reduce

emissions of carbon dioxide into the atmosphere led to heated debates around the Paris Climate Agreement. Someone sees in it a concern to reduce the anthropogenic impact on the planet; someone (e.g., Great Britain) uses a climate agenda to protect its market. There is an opinion that the global markets have a problem of carbon protectionism, which can lead to sanctions pressure on the national economies [2]. In this context, the US withdrawal from the Paris Agreement is simply protection of the national business.

If you take the problem more broadly, the whole history of the struggle for sustainable development is in fact, the history of the struggle of the population for the environment, and for entrepreneurs, it is for profits. And, if large plants and enterprises can afford pollution control facilities, then for middle and small businesses, it is often too expensive. Thus, the choice between profit and environment among the majority of entrepreneurs in the world is obvious. Almost the only deterrent for "ecologically irresponsible" is the regulatory role of the government in the area of environment protection, imposed penalties, sanctions, etc. Of course, there are entrepreneurs for whom taking care of the environment is not an empty shell, but most often profit comes first, and environmental expenditures with whatever remaining funds the firm has. The most environmentally conscious are sufficiently young people who grew up and received education at a time when environmental problems became relevant and discussed. As practice shows, if a person received an environmental education since childhood, a businessman and an ecologist can make a compromise in his mind.

However, in Russia, as in most emerging countries, there is practically no formal educational policy in the field of sustainable development. In this context, initiative projects are of particular importance. In our work, we analyze the experience of the partnership between Ural Federal University and schools in the field of sustainable education. We call such projects university-to-school projects. The rest of the work is organized as follows: in the next section we briefly described the background of sustainable education, then we analyzed the case of Ural Federal University; in the Discussion and Conclusions section we tried to interpret the results and formulate the insights.

2. Background

Sustainable development was originally conceived as a political concept in the late 1980s. The first definition of sustainable development belonged to the Brundtland Commission, which defined it as a development in which the needs of present generations are met without compromising the ability of future generations to meet their own needs [3]. Thus, at its earliest meaning, sustainable development was associated with the maintenance of the environment quality [4]. Over time, the concept expanded. A more modern interpretation includes environmental, as well as economic and social dimension [5–7]. The UN Resolution [8] introduced the vision of sustainable development: *We envisage a world free of poverty, hunger, disease and want, where all life can thrive. We envisage a world free of fear and violence. A world with universal literacy. A world with equitable and universal access to quality education at all levels, to health care and social protection, where physical, mental and social well-being are assured. A world where we reaffirm our commitments regarding the human right to safe drinking water and sanitation and where there is improved hygiene; and where food is sufficient, safe, affordable and nutritious. A world where human habitats are safe, resilient and sustainable and where there is universal access to affordable, reliable and sustainable energy.*

The vision emphasizes the role of education in building the future. Speaking about sustainable education, the authors of the article do not mean gathering recyclable materials, feeding birds in winter and participation in ecological events. Of course, these are essential components, but not the most important ones. Several studies showed that the growth of professional knowledge of scientific, technological, and socio-economic nature directly affects the possibility of the transition of the territory to an innovative development path [9]. Thus, in order for a "greening" of production to take place, there must be an increase in the general culture of people in this area. The most important result of the intellectualization of the population of the territory is the emergence of an intellectual and

innovative space. A new type of behavior is required for its functioning, not only for individuals but for the social and economic systems as a whole.

Intellectualization of the population and the various innovations arising on its basis cannot come into being in a short time. Any society needs a relatively long period of time for its maturation, which first includes the accumulation of knowledge, and then turning it into a way of thinking for the bulk of the population. Intellectual loners can only offer original ideas, describe them, and even make prototypes, but only collective efforts of the majority of skilled working force can transfer the ideas into mass production.

As a source of knowledge accumulation and generation, secondary and higher education moves to the forefront in the development of sustainable society. Relevant skills and competencies are essential for implementing the paradigm of sustainable development [10]. Competence-oriented programs have been recognized as a critical factor in the transition of education to the path of sustainable development [11]. This concept has been supported by numerous empirical evidence in the form of best practices [12, 13]. Nevertheless, most discussions about the formation of competencies relevant to sustainable development are conducted in the context of higher education [14–16].

We believe that sustainable development requires not only skills and competencies but also the formation of stable patterns of thinking. And here secondary education comes to the forefront because the formation of mental models at an early age is much more effective. We all study at school from 7 to 16 years. In the junior classes, natural science lessons are usually conducted, and then during the course, the students are given an idea of the environment, the basics of ecological knowledge. There are Olympiads of ecological direction for pupils of schools. In some schools, the children, under the guidance of teachers or supervisors, write reports or conduct feasibility studies (often analysis of data from the Internet) on environmental topics. After entering the university, unfortunately, school work is lost. This is due to another organization of studies so that at the graduating departments (apart from specialized ones) sustainable development or ecology is not the main subject. As a result, a person has acquired some skills in the field, but a way of thinking has not been formed. In such a society it will be indecent to litter, it is young people who are quicker to get used to throwing out garbage separately, but there is hardly any innovative breakthrough in the field of sustainable education right now.

3. A Case of Ural Federal University

The authors of the article believe that it is necessary to use school environmental practices from the first days of study at the university. It is essential to involve students in solving practical problems. Those, who consciously engaged in environmental problems at school, take this work willingly. Only the task should not be narrow, but rather large, including knowledge from different areas. As an example, we can cite the disposal and treatment of polluted waters of small CHP and thermal power plants. The main sources of hot water supply and heating are also the main sources of pollution of the living area due to its location. Losses of CHP and TPPs with heat supply to consumers increase depending on the distance. Therefore, historically, many of them are in the urban environment where it is simply impossible to place cooling ponds, sludge accumulators, etc. At the same time, one can use a variety of heat exchangers, scrubbers, etc.

As a result of technological processes, a large amount of contaminated water is emitted during steam condensation at any CHP and TPP. An even larger amount (10–15 times more than has been discharged) is needed to ensure that condensation and cooling of the discharged water occurred in the end. The most conservative estimates show that even a small CHP plant incurs significant losses as a result, and if you add the cost of water treatment and the cost of its disposal, the amount looks impressive. Besides, CHP and TPP use water for washing boilers and other mechanisms. Thus, if this water is returned to circulation for reuse, then several problems can be solved simultaneously: reducing water consumption, reducing heat pollution, obtaining an additional product, which will make the work more attractive in the eyes of potential consumers and investors.

Such work has been conducted in Ural Federal University since 2008 under supervision of M. Volkova, exclusively by the students of volunteers who are not engaged in specialized

departments, in their spare time. It should be noted that the problem involves a fairly large range of issues: from the creation of a purification technique with the help of developed biofilters to the study of the issues of complete utilization of filters. In different years, the team of students changed, and the range of tasks varied. Each of the students can choose the direction by which he will work. For example, the construction of a prototype is closer to the builders, the utilization and production are for physicists, the specialists in the field of biochemistry conduct a study of optimal conditions for the operation of biofilters, etc. Students publish their work; as a result, ecological thinking has been formed, what is more important. Students start to think and think a little differently.

The team of which we are speaking is quite unique. Its composition changes regularly, all students are of technical specialties, the basic principle is voluntariness. The work in the research team starts from the first to the second year, there is no compensation and funding. At the same time, our student team is working on a very topical issue. The head of the team wants to show that the protection of the environment is by no means such a costly expense item, as it is commonly believed. Teams of similar-minded people wishing to improve the ecological situation are quite capable of solving environmental problems. The need for such work, in the authors' opinion, is shaped by the educational component, in addition to the environmental one.

Thus, there was a desire to attract students to scientific work, in order to broaden their horizons and develop their creative abilities. The involvement of students in solving practical environmental problems proved to be very effective. Students' engagement from the first years of study empowers a system of continuous environmental education. Creativity enables personal freedom, unites similar-minded people, and distracts from reality. We are convinced that such teams are an excellent opportunity for the integration or inclusion of students with disabilities. Students with disabilities can realize their potential at creative discussions, when studying or processing experimental materials, etc. If the state of health does not allow them to participate personally, then the modern means of communication allows these children to communicate remotely. For people with disabilities, much is done in the sphere of creating an accessible environment, but we are sure that the most important thing is the sense of necessity and usefulness to others. It really can be achieved through the work in creative teams. It enables communication with others on an equal footing, a realization of one's thoughts and projects, and in the end, raises self-esteem.

What attracts students in a job that is not paid and been done in spare time? According to the results of unstructured interviews with program participants, this is:

- A possibility to develop creative ideas;
- An opportunity to participate in the scientific conferences. Maybe in the future, the student will not become a scientist, but an experience of public presentations is always useful. The first presentations are usually very "stammering", "stuttering" and not the most memorable for the audience. After a year or two, they are already self-confident speakers, quietly communicating with the audience. Perhaps, the only thing that remains for students to remember about their work is certificates, presentations, and publications.

On the basis of the data obtained, the team of researchers developed a schematic diagram of the device, which has such advantages as compactness and wastelessness, can be easily adapted to particular features of the production process. Thus, from the original idea, thanks to the initiative of students and proposals to explore this or that aspect, the project divided into three parallel studies:

- Application of purified water (for irrigation and plant cultivation);
- Studying the possibility of obtaining biogas from biomass grown during the purification of condensate;
- Development and improvement of the machine itself (patent documentation is being prepared).

There are quite a lot of issues that require closer examination and study in the future. Our team participated several times in the competitions to receive funding from UMNIK1, obtained good

[1] The program of the Fund for the Promotion of Innovation, which finances youth projects with scientific novelty. URL: http://umnik.fasie.ru

reviews. Therefore, there is a hope that sooner or later, but we will have funding, and all the projects, temporarily postponed, will be brought to an end. Fortunately, there are many creative children in our country, and they have a desire to contribute to the improvement of the environment. And most importantly, such people, whatever they do in their lives, will be able to rally around themselves like-minded people. There are interesting studies and real proposals, and this despite the fact that everything is done only on enthusiasm. Simply, the students are given an opportunity to realize their idea and do something interesting and necessary. Not all of them are enrolled in post-graduate or master studies in the environmental field. Most often, for each of them remains a shelf with their published works in memory of the work. For someone it is more, for someone it is less, it is not so important. The main thing is that students have a clearer understanding of the environment as a science. Some of the students continued their education (and the articles helped with the admission to the post-graduate or master's program), someone found a job.

Nevertheless, you can start this work even earlier. Beginning with grades 7–8th, a sufficient stock of knowledge accumulates among schoolchildren, as well as their desires to apply them in practical tasks. A striking example is the *Ural Project Session* held for gifted schoolchildren by Ural Federal University. To participate in the Session, the schoolchildren passed a contest, to which pupils from the 7th to the 11th grade were admitted. The work was conducted in several directions, one of which was *Intellectual Energy Systems*. Within the framework of the Session, the project *Purification of technical water from power plants using simple algae* was developed. The team consisted of 5 people (2 students of 11th grade, 2–10th, and 1–8th). The students not only perfectly understood the problem, but they also developed and assembled a workable prototype.

The device consists of three filters (Figure 1). Contaminated water entering the pipe into the first filter (far left) is subjected to primary purification from coarse contamination. In the filters 2 and 3, there are algae, due to which the polluted water is saturated with oxygen and changes the hardness. Indications of temperature, light, and hardness are automatically controlled by sensors on the control panel. In the case that the sensor shows a decrease in the hardness to a predetermined value, the valve automatically opens, and the purified water returns to the system or goes for technical purposes (on the stand it is a tap). If the water does not sufficiently reduce the hardness, which is controlled by the solenoid, then it returns to a new cleaning circle. Thus, a closed cycle enables the water to be purified to a predetermined value.

Figure 1. The water purification machine assembled by schoolchildren

The idea was so interesting for the schoolchildren that even after the end of Session the team did not fall apart. The guys themselves created the group NP Team in the social media and now actively participate in grant competitions. There is intent to continue the development of a comprehensive method for cleaning contaminated water from the CHP plants. The only deterrent is the final grade of the school this year for two of the team members.

Now the team is preparing to participate in the Ural Project Session in the educational center Sirius (Sochi). 100 students, who have successfully passed the competitive selection, will attend the Session. Students of public, municipal and private educational organizations located on the territory of the Russian Federation in the regions of the Urals and Western Siberia are eligible to take part in the competition. The purpose of the Ural Project Shift is identification, development, and support of gifted students in the field of design and research activities. The tasks to be performed during the Session are as follows:

- Activation of creative, cognitive, and intellectual initiative of students who showed interest and inclination to study mathematics and earth sciences;
- Identification and support of students who are prone to research and development activities;
- Generalization and development of the best practices in the studying of mathematics, physics, chemistry and biology in the upper grades, namely, preparation for Olympiads, development of research and educational projects, organization of extracurricular work of students;

Engagement of scientists, specialists from research institutes, higher education institutions to work with students.

4. Discussion and Conclusions

Of course, sometimes the students do not have enough knowledge, but enthusiasm and the desire to apply their knowledge in something important led to this result. Probably not all of the team will associate their lives with the environment in the future, but the more such programs are available, the faster the generation will grow with a sustainable way of thinking.

It is not justified to consider that the work of schoolchildren and students is insignificant and has no practical significance. Of course, there are a lot of ways to reduce emissions at CHP and TPP. Practically all methods of reducing the environmental load are quite energy-consuming, expensive, and often cumbersome. All of them are developed in the research institute, by a large team. Pupils and students do not have such a financial opportunity, so they use more democratic materials in their studies. The result is a fairly inexpensive and more attractive product. Thus, solving a specific applied problem it is possible to form an active position in relation to sustainable development in the younger generation.

Let's look at the problem from the point of view of institutional theory. We understand institutions as a set of formal norms, informal constraints, and coercive mechanisms [17]. In a broader sense, institutions can be divided into 4 groups:

1. Normative – norms, rules, customs, standards, conventions, contracts, etc. [17];
2. Functional – status functions and routines [18, 19];
3. Structural – organizational forms and models of transactions [20];
4. Mental – collective representations, beliefs, stereotypes, values, cognitive schemes, etc. [21].

Normative institutions are among the most rigid formal institutions that rely on violence as a coercive mechanism. As a rule, it is the government that relies on this type of institutions. Routines are repetitive, normal and predictable procedures for solving similar problems. The theory of structural institutes was developed for the firm level, but this model operates at the national level as well. It determines not only the structure itself but also the model of interaction of various elements of the system. Finally, mental institutions or mental models imply a similar perception and interpretation of reality. The core of mental institutions is values that are an integral part of the culture of the individual and society as a whole. At the same time values are divided into absolute, which the individual always follows, and relative, which are conducted only when it is profitable.

Functional and structural institutions are derived from normative and mental; so, we can define the latter as primary institutions. According to the authors, the importance of mental institutions is greater. The adoption of regulatory institutions is determined by the transaction costs of accession and evasion: if the transaction costs of evasion are lower than the costs of compliance, a person will choose not to comply with the norm. In the case of mental institutions, the transaction costs of evasion are extremely high, because they are supported by both the social and the internal mechanism of moral evaluation. The costs of changing mental institutions are also very high. Therefore, we can conclude that only people with stable mental models of sustainable development can guarantee a sustainable future. This does not negate the role of normative institutions in the transitional period because the formation of mental institutions takes a long time (at least one or two generations). During this period, normative institutions create hothouse conditions for the development of mental institutions.

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