László Z. KARVALICS

Students doing and producing science

The missing last mile in digital science pedagogy

„And to whom we wish to convey our knowledge

Already lives his life as a scholar"

(Oszip Mandelstam)

Introduction

Máté Nászai had been at the first course when he had started his experiments on a mini bio-gas power plant fed with bacteria that would be able to provide energy for his school (Miklós Radnóti Secondary Grammar School in Szeged). Ten years ago when, at the age of 15 and the second year of the school, his work was presented in a newspaper article (Hargitai, 2009), his current research challenge was to jump from the ten-litre size to one cubic metre. And although he was given theoretical support and microorganisms by the relevant department of the University of Szeged, the work he carried on together with his teachers and peers, which was aimed at the development of a new biotechnological know-how, must be considered an *independent applied research project*.[1]

Let us see an example from the world of basic researches, too. The youngest author of the gravity centre of scientific publication products, the Nature, fifteen-year old Neil Ibata contributed to the theory of galaxy evolution when, some years ago, his simulation proved of the dwarf galaxies rotating around the Andromeda that their motion is not chaotic; they form a huge but systematically moving structure through 1 million light years (Ibata, 2014).[2]

We could go on telling several similar stories from each part of the world. It was always clear that after a certain age, some students' performance might reach or even exceed that of the qualified members of the scientific community – or at least can be compared to that in some respects. It was not questioned in the pedagogical tradition either that the contribution of school environment might help child prodigies (wunderkind) create full-value scientific results by "adding" to the "brought" family, cultural and socialization elements.[3] This was clear already at the beginning of the 20th century – in Hungary, too, where it was not only young mathematicians and chemists but "literary historians" and "ethnographers", as well, who approached reviews and editing publications directly from the school

[1] The young scientist's way led from here to national and international student competitions (including the golden medal of the most dignified one, the International Biology Olympiad) and the renowned University of Cambridge (2011-2014); then, skipping an education degree, he started PhD studies at the University of Glasgow in oncology (2014-2018). Since having gained his scientific degree he has been working here as a research assistant.

[2] It does not lessen Neil's merits that he made his discovery as a Python programmer "helping" his astronomer father's research; he published another aspect of his discovery in a review of astrophysics in the very same year, with some other peer authors.

[3] In case we want to pry into the reasons of creativity, innovativeness and the possibility of becoming a child-scientist – as Ginsburg (2011), Tough (2012) or Ripley (2014) did it –, we will get into a much more complex field since several more, unexplored or not sufficiently understood factors might act. Walter Pitts, one of the founding fathers of artificial science did not bear any of the attributes when, as a 12-year street kid of Chicago, he took shelter from a gang war at the public library, and, without any preliminaries, within three days he discovered several mistakes in Russell's Principia Mathematica. See the story at: https://hsm.stackexchange.com/questions/7393/what-were-12-year-old-pitts-objections-to-principia-mathematica (Each content at the referred URLs was downloaded on 19th June 2019.)

bench. István Hajnal conceived it that although medieval "*French universities had no notes about their students, based on the biographies we can highlight several examples of students younger than ten years old but attending university lessons; contemporaries often spoke of prodigy children who recited Latin authors by heart already at this young age"* (Hajnal, 2008: 99). [4]

Sciences and students: some basic narratives

> *„The two fields of creating knowledge are research and education. While scientific research produces new knowledge, the function of education, and primarily of organized school education, is to direct the processes of gaining knowledge and learning"*. (Csapó, 2004:1233)

In case we pair the perception and the interpretation of fantastic student performances and the latest discourses on the education of sciences at school, we will find several common moments that can certainly be called the reigning opinions heavily dominating the theoretical starting points of the topic:

- *Sense of being special and exclusive:* The capability to do full value scientific work is an extraordinary state, it is not part of the "target functions" of school, it does not need deeper reflection, and it is enough to accept that "it can happen".[5] Similarly to vocational teachers' readiness for sciences: it is not bad, it is even good if they have it but they are not required to.
- *„Being outside pedagogy and school":* The extraordinary students' scientific capabilities do not have any impact on the requirements, notions and "philosophies" connecting to the education of sciences and school subjects. It is not even raised as an issue to integrate the phenomenon into scientific education at schools in the hope of massification or some kind of emancipation. It automatically belongs to somewhere else, the world of *talent education*.[6]
- *At the same time, the perception and the definitions of talent* become narrowed to proving and measuring progress in reproductive knowledge of subjects amongst competitive conditions. Of course, a lot more of the student subjects involved in additional classes, study circles and special laboratory work will become scientists later, however, school knowledge processes are sensitive to *skills-base immersion* in the micro cosmoses of vocational scientific knowledge: what happens is *the individual multiplication of the knowledge already created in the scientific sub-system at the highest possible level*. The "most talented" ones are those able to possess and use most of the science distilled into learning materials.
- Composing the talents consciously together (talent groups, talent classes or talent schools[7]) *learning objectives* can be accomplished even more intensively, and it is still not providing juniors for science that is in the focus but the unfolding or development of the students' skills

[4] In his Supplementum Chronicarum (1483, Venice) Jacob Foresti steps beyond the mere recognition of the situation when asking: *"Why shall we prefer old people against their students while diligent studies may open the way towards the very same knowledge for young people?"* (Logan, 1986: 195).
[5] Of course, this implicitly presupposes the "unscienceability" of the major part of students.
[6] The KutDiák (https://www.kutdiak.hu/hu/), the movement of student researchers has reached outstanding results highlights about itself is that it opens a way to *"knowledge and a way of thinking unapproachable from the school bench"*. It takes place at the top of the talent education pyramid: it offers personally tailored and complex support for the few most apt for scientific research so that they can try how far they get as student scientists.
[7] Elite secondary grammar schools and elite schools – owing to their obtained prestige and attraction – build, as a matter of course, their work on children of good capacities. It is worth reading the report on the "school of talents" in Novosibirsk in the mid 70's (Malita, 1976:302). Comparing to this, we can judge worthily the "wonder classes" of Andy Bramante, the teacher of Greenwich High School where average children became innovators and winners of scientific awards not because of its rigid "racing stable" nature but because of the pedagogical methods allowing wide freedom (Tesoriero, 2018).

at a higher level in the hope of their improved labour market chances and life perspectives, in an independent talent pedagogical field.[8]

- If research process appears in any form, it primarily and exclusively *serves learning*. *“Learning by research*” (LbR), as a methodological paradigm became, relatively rapidly, a practice used at the lower levels of public education from a solution supporting the independent learning skills, evolving through the autonomous selection of their topics and research strategy building, of the students in higher education (Roberts, 1994, Schallies and Lembens, 2002). After a while, this method was attended by „*Learning by Collaborative Research*” (LbCR), the pedagogy of cooperative research communities built of students and completed by the training of teachers and the measurement of learning efficiency (Christianakis, 2010, Golfomitsou, 2017). The very popular trend of *inquiry-based learning (IBL*) seems very similar[9]: however, in fact it only concerns the teacher’s role that transforms into facilitation from knowledge transfer and the techniques of classroom work that improve the efficiency of learning the knowledge packages by increasing the level of interest and motivation. Literature, some part of which is sensitive to the collaborative/community dimension, as well (Wells, 2001), keeps that the target function is “learning outcomes of higher standard” and the foundation of life-long-learning at school (Nagy, 2010). Today, this prevails in nursery school pedagogy, as well, and it is not exaggerative to say that it is absolutely focused at natural sciences.[10]

The listed points of theoretical outset mean a border to which theoretical thinking (be it pedagogical philosophy, educational policy or subject didactics) only approaches but never jumps across. Luckily, in practice one can see several examples that it is possible to escape from this conceptual pillory, and pedagogical practice is faster and more flexible in adapting to comprehensive civilizational (social macro-evolutionary) changes. The digital ecosystem and information culture that, in addition to communication and knowledge acquirement, affects and transforms more and more existence layers of everyday life has long been pointing beyond this imagined border line. And we should not search for the reasons in the organizational and methodological world of school. If Digital Pedagogy reflected to the challenges set by *networking, the tool environment* and the organization of educational content adapting to these (adaption), Digital Pedagogy 2.0 (Benedek, 2012) probes deeper, and is perceptive to the transforming nature of *processes and structures* (transformation). In case there will be Digital

[8] It tell us a lot that the *Gifted Child Quarterly***,** the review of the National Association for Gifted Children (http://www.nagc.org/) has been published since 1957 (https://journals.sagepub.com/home/gcq). It is also clear that the engine of the talent train is motivation coming from parents, therefore talent industry is a lot wider than the school dimension, especially since the online revolution when lots of parents have hoped to fabricate their children into “above-the-average” by means of special (and expensive) devices, courses or education packages. Of course, the distance between the education-development programs setting developed educational objectives (for example: http://www.minieinsteinslearningcenter.com/) and the market stakeholders established to sell products (for example, Disney’s Baby Einstein company https://www.pgpedia.com/t/baby-einstein-company) is enormous.

[9] For the first meeting with the concept of IBL, it is suggested to read the thorough and regularly refreshed Wikipedia article: https://en.wikipedia.org/wiki/Inquiry-based_learning

[10] To accept all this is enough to have a look at the “Bible” of the issue: the 2007 report of the EU’s Directorate General for Research and Innovation (Rocard, 2007), that considers the renewed pedagogy of future Europe as equal in value to the more effective (research based) education of science, and finds the reason of its mission in the decreasing interest in sciences (especially the STEM subjects), which might lead to labour market and competition disorders in case we do not “set right” the pedagogical foresight in time. And research-based nature became the “Saint Graal” of the report because the scrutiny of “whys”, of the reasons came to a deadlock at the weaknesses of the methodological culture of science teaching and the low efficiency of the teachers’ motivation work. In the report welcomed as a revelation, the mission of which is to “pave the way for a new pedagogical culture”, I can see nothing else but the actionist substitute by a declining educational policy (necrophilic, with Freire’s words) arising from a narrow-minded situation analysis. If compared to desk teaching restricted to reproductive knowledge, research-based education is undoubtedly more up-to-date and efficient – however, it still builds on the objective and tool set of the very same “old” pedagogy as its ancestor, instead of new pedagogy adapted to the changing world.

Pedagogy 3.0[11], it may provide a framework for adjusting the principles, objectives and practices to the *changing image of the world and the child* (social innovation with a planner's thinking). And how could we speak of digital science pedagogy within this field in case we do not analyse the system level changes in science itself and do not try to draw the outlines of Science 3.0 (Z. Karvalics, 2007, 2008a)?

Science and digital culture: message from key developments to school

„science is too important to leave it only to scientists"

(Doug Schuler)

In the next sections, I will mention only the changes of science that are meaning and interesting in terms of the future of science pedagogy, as well.

The primary and most visible direction of the transformation of knowledge plants is the increase in measure and complexity. Bigger and bigger scientist communities are using more and more enormous and so more and more expensive mega-machines that can mostly be built only in international cooperation (space stations, space telescopes, gravitational wave detectors, particle accelerator, laser physical centres etc.); signs that are issued by these tools (as the prime producers of the scientific Big Data) and require analyzation have multiplied many times, as well. In parallel, the spread of automatized signal processing and solutions of artificial intelligence replace some of the scientific routine activities (similarly to other segments of the labour market). On one hand, this allows researcher lifetime move to domains of higher added value and, on the other hand, raises the needs for the implementation of tiny research *micro tasks* not possible to be automatized. This needs supplementary human resources, and this auxiliary army is more and more available due to the high number of volunteers organizing into network communities. And while, technically, this is one form of crowd sourcing, *citizen science*, too, has stepped into a new era. In fact, online database and transaction management have allowed the evolution of cooperating research communities of astonishing sizes: several hundreds of thousands of people (or even million in the Zooniverse / Galaxy Zoo projects initiated in galaxy classification). Some parts of the micro tasks can be fulfilled in a playful way, as well: the platforms built to "wrap" protein structures are extremely popular. Most of the citizen scientific projects deal with local-environmental-nature protection issues.[12] But new possibilities appear this way not only in natural sciences but in the world of cultural heritage (Golfomitsou, 2017) or even history and literary sciences, as well.[13]

The many volunteers offer many material resources, too. Smart phones that serve as mobile laboratories; applications apt to be used for scientific aims; cheap webcams that allow us to glance into the lives of bird nests. Many offer the unused processor time of their computers, and by doing so they contribute to satisfying the calculation needs of scientific projects demanding in signal processing.

[11] Interestingly, we can find methods of systemization (after the example of Web 3.0) that announce the birth of Education 3.0 or Pedagogy 3.0; these, however, do not approach from digital transformation, its elements are only the attributes of the comparisons.

[12] These are joined by many pensioners and students. And the fact that this symptom is really fed by the resource demand of science is clearly reflected by Tóth's remark (2004) about domestic scientific student camps where young people *"… could do scientific observations and examinations that were not undertaken even by renowned research institutions. Not only because of the lack or being busy of their researchers but also because these researches need high numbers of participants. Like, for instance, synchronous ornithological observations, the close examination of a loess lawn or mass soil sampling on a saline territory".*

[13] The digitalized and published photo and document data bases of museums are supplied by family members and volunteers all over the world. In the famous Breitenau research the stories of the individual victims of the labour camp employing only Germans of Hessen and Thuringia were followed by students of 14 or older: http://learning-from-history.de/International/Posting/8553 .

Others offer money or transportation capacities for researches. By doing so, the civil society has joined line with companies and science policy as an agenda setter affecting the trends and possibilities of scientific researches,[14] and science itself is partly becoming "open science".[15] Owing to this, new, participative channels of reflecting to civilization problems have opened up. The social contribution of science is not any more merely the dissemination of its "blessing" but active participation in processes of gaining knowledge; by establishing personal relations and forming own questions and demands.[16] In light of these facts we can understand the importance of *science journalism*, the network dissemination of scientific results and the several amazing platforms of popularizing science in age groups[17] because it deepens the *scientific literacy* of consumers increasingly impressed by science. (Z. Karvalics, 2013a).

The demand for citizen science is growing in parallel with the extension of the results achieved in the cognition of "more extensive terra incognita". It is inevitable that the existing self-motivated and spontaneous forms be completed with systemic and institutional solutions by utilizing the experiences and best practices. And no doubt, the frameworks for this are already available, amongst others, in the form of the mental, material, cultural and human capital of public education. Science pedagogy can meet the epochal challenges if it steps forward and *besides learning science it also includes doing science into its program*. This needs a radical change of attitudes. A giant step by which former borders can be crossed, and all the difficulties of the "final mile" overcome. The ten theses that present the most important arguments and statements that point towards the school revolution of doing science mostly as the "antitheses" of the current practice wish to support the theoretical foundation of this turn. In this part of the paper, I refer mainly to my own former publications because in these I introduced the aspects and conceptual innovations presented here more extensively and in more details.

Producing new knowledge at schools: ten normative theses

Joining in current scientific programs and successful contribution to them must gradually become a standard part of school curricula

The elements of scientific literacy and the acquisition of scientific methods will only become an organic whole and a meaningful, activity-organizing element from partial knowledge if science is done actively alongside. However, the microtask-type[18] possibility of participation presented so far is only a kind of an "entrance level" of this: the way towards the higher level operations of producing new scientific value is open, as well (even to generating and testing hypotheses that contribute to open scientific discourses). Meanwhile, building in the cultivation of science does not "replace" the traditional vocational curricula but enriches them with a new module. Its philosophy is: not to terminate former

[14] It was the *Crowdsourcing and Citizen Science Act* having come into force in the US on 6th January 2017 to recognise this first and draw the necessary conclusions (Z. Karvalics, 2019a).

[15] The narrow understanding of "open science" only covers the publicity of and open access to scientific results; the wider recognition, after the collapse of the former walls, means that the space for doing science includes more and more participants – just like the concept of "open innovation". The "open movement" is an approach that considers the new world of collaboration and sharing as a power transforming education and science at the same time (Jhangiani and Biswas-Diener, 2017), while Hecker (2019) sees citizen science as the source of the pressure creating the new dimensions of society and politics.

[16] Barell (2003) included the strategies of this "personalization" into his book. It is easy to see that the exploration-based approach is only *one* element in the much richer set of motivations where personal affection and the capability of putting independent questions about the natural-social-community environment. Or conversations with astronauts or Arctic explorers in real time, which offers the possibility of getting inspired: it is the world of real personal affection. Problem and solution communities may arise only from here.

[17] Like e.g. the Mad Science Kids Club (https://www.madscience.org/), where advance is supported by the interactive Lab Rat or the Science News for Students https://www.sciencenewsforstudents.org/ (earlier: Science News for Kids). See more details in: Z. Karvalics (2015).

[18] The 2.0 "prototypes" of microtasks are *micro content task systems* (Horváth, 2012).

priorities but raise a new one besides them. Its undertaking is moderate: it is aware of the fact that only certain programs of certain scientific fields are apt to implement researches within the "school architecture" frameworks.

Participative science is a type of experience, skill and task to be provided not only for "talented children" but **all** *children in public education*

Just as the trinity of 3R (*writing-reading-arithmetic)* meant in earlier times the "common minimum", in digital culture these have been attended by *information literacy* that we can take as the new literacy acting as the condition of active netizenship. Seemingly, scientific literacy accomplishing itself in participation is not a competence the lack of which endangers life perspectives (just as it is possible to live a perfect life with difficulties in writing, reading or calculating). It is, however, more reasonable to put the question this way: how can we argue for not making a general requirement of this aim that is achievable from a pedagogical point of view? Horribile dictu: it is a human right (Z. Karvalics, 2019b). In case a child of evolving mind is like a small scientist (creates categories, asks questions, forms and clashes hypotheses, struggles with meanings and follows the widening circles of cognition through notions and models in order to explore the world), why should anyone be *excluded* from the continuation of this process? During preparation, the pedagogical praxis of the tradition of *critical thinking* (for which the Hungarian phrase is child philosophy) can be used[19], which can beneficially be completed with methods helping the correction of gained disadvantages.

While doing science, learning becomes an objective serving research capabilities

As we have already seen it, the research of "as if" nature, the essence of which is "it should be done this way in case it were real" serve learning processes. When the students are integrated by real researches of real stake, the relation turns around. The prior knowledge necessary to do the operation becomes the precondition of quality assured participation. Directed learning, which is controlled by the teacher as a gate guard. The range of necessary knowledge varies from project to project, but for the teacher it is a great help that it is not authority and the mark that give the student's motivation to learn but the will to become able to join the project. During the planning of the research, the scientist and the teacher's common work prepares the learning phase (Cooper and Cowie, 2010), and the teacher in each case makes an individual decision on which acquired "part of the learning content", as compared to a traditional curriculum, can be replaced by getting deeply engaged in the research.

"Doing" science at school at the same time means founding "lifelong research"

In case joining in performing sciences is general and of mass measures, the school may be the controllable "entrance-training" level of citizen science. And just as joining network scientific programs has been voluntary so far, after quitting school, everyone still has the possibility to participate in programs according to his/her interest, value set and choices if (s)he wants to. Only, not in a spontaneous but in a pre-educated way, by means of pre-education, meeting higher levels of challenge. In other words: public education is the launching station not only for lifelong learning but for *lifelong research*, as well. (As part of the re-calibrated social responsibility of schools.)

[19] Let us also also add that the successful phase of Hungarian adaption getting under way with translations, books and teacher training was followed by silence, so it is high time to reconstruct the domestic school of critical thinking and get to know the latest international results of the previous decade. Similarly, it is worth "getting back" to the action experiment of József Zsolnai's science education at Zalabér.

Scientific programs of mass and big volumes require adequate infrastructure and research environment

Certain teachers, certain classes and certain schools themselves can only start projects of limited size. (Although there are research types that do not need an online hinterland, and take the children to nature; for these, the ideal size is “some classes”, 150-200 children, which is easy to organize.) The projects running on the network and based on micro tasks, however, require consent and digital platforms developed especially for this aim where topic proposals that inspire choices appear, decisions are made, the research community is built, productions are aggregated and the results are introduced.

These platforms are not yet available.[20] Their introduction, taking into use and “habituation” may take longer time, while further developments serving the new demands must also be made.

By means of the active participation in creating scientific knowledge the pressure of acute pedagogical problems slackens

A scientific branch squeezed into a (vocational) subject and a schoolbook and the ways of learning and checking are, despite the teacher’s all effort, strong “challenges” for the students. And especially as compared to the digital world being, as the citizens of which they enjoy a very high grade of freedom in choosing activities and are self-confident in gaining competences in performance (be it about gaining knowledge, games, using apps or doing transactions). However, owing to the recognized and experienced “importance” and “meaningfulness”, through participation in a voluntarily selected scientific project, personal contribution to a wanted and expected common result *becomes an internal need from external obligation*. *Loyalty attended by respect for authority is replaced by interest attended by the sense of responsibility*.

And let us not only think of the students. All these hide special perspectives for the (vocational) teachers, as well. Formerly, they, too had to choose between doing or teaching science; bringing knowledge production into schools considerably eases the absoluteness of this forced choice. From an examination body, the teacher advances into being a coordinator, project manager and supporter. The base for his/her authority will be his/her competence appearing in various dimensions of the research process. *Power-based asymmetry turns into collaboration*; teacher and student make one team. Compared to the repetitive use of the unchanging curriculum, all this raises strong demands in terms of following the latest developments and interesting discourses of the given scientific fields, searching for entrance points, conscious self-education, forming bold own dreams, search for partners and communication and interaction between scientist and teacher (Cooper and Cowie, 2010). Thus, to build a new teacher identity layer.

New knowledge can be created not only in the domain of science but in the world of technological and social innovation, as well

Similarly to students’ results in the basic and applied researches presented in the introduction, an independent study could be written about the technological developments that have arisen and been implemented from school desks. Some of these (e.g. pharmaceutical researches or new types of

[20] The “*Palaestria”* program has been going on since 2007 at the University of Szeged; during the program, we have organized pilot projects (e.g. space archeological field research with secondary school students of Csongrád county), and a pilot web page had also been launched. This early platform was overthrown by the revolution of applications and smart phones, but was born again on a 3D base in the summer of 2019, under the name Studiolo, with a community media module and the support of the Hungarian UNESCO National Commission.

medical tests) cannot spare scientific background, but these fields are less suitable for mass collaboration. However, community based searches for solutions[21] sometimes require the common efforts of many people; these are either of a scientific nature, or sometimes need technological innovation or implementation, or in other cases simply need a *social innovation* taking us further towards the establishment of a wished future state of affairs. When a nine-year-old girl develops the prototype of a cheap and easy-to-build homeless hut, and also prepares it, or when whole classes in cities collect food for village families, or student informaticians operate and maintain school web pages and background systems[22], they are the active participants of real stories and do not learn through "like-spectacles". In the Hospital School project, students make personally tailored digital learning content[23] by which they help their peers staying at hospital to make up for subject lag. This is *participative knowledge technological development* of full value, which is motivated by the patterns of recognized and experienced solidarity. The very same thing happens as it does in scientific projects: without intense learning attained through inherent motivation development cannot be successful.

The projects of various scientific fields can be started independently or hybridized with technological, social and arts dimensions

Arts succeeded to get included in the STEM (Science, Technology, Engineering and Maths) quadruple that had been born in the '80s of the last century; this is how STEAM[24] was born about twenty years later. However, a narrowing and elitist interpretation of the acronym became dominant. It did not only express the fact that these five fields are connected but also that it is *primarily* these five knowledge worlds that must be preferred from public education to higher education (in many cases quite openly with the background argument that these are the clue fields of fulfilling the innovation potential and the labour market demands). Today we already know that all of the arguments lack ground (Z. Karvalics, 2008b): labour market demands *social skills*, and information and material technological industries are joined by *human technology and human economy* (Z. Karvalics, 2019c). But if it were some other way, "non-STEAM" subjects (history, literature, language, philosophy, social geography or physical education) would still not be of lower rank, although some of the education and science policies take this as evident. And this even more applies to them if mentioned as possible fields of scientific research: here, the acronym needs to be completed with *Society, Humanities and Community engagement*.[25]

Thus STESCHAM could perhaps be the fantasy name of *the integrated school "knowledge domain"* including all possible fields. Meanwhile, one can define less and less projects being sensitive of just one piece of knowledge. What technological philosophy calls "*entanglement*" can manifest in the world of potential community researches, too, in several ways. (With various hybrids and "directions

21 https://www.livingknowledge.org/fileadmin/Dateien-Living-Knowledge/Dokumente_Dateien/Toolbox/LK_A_DIT_CBR_Process_Map_Sept_2015.pdf

22 All his can be compared to the emptiness of the "prodigy child discourse"; for example, the silly competition for the record of the youngest Microsoft system administrator. The title was gained over from the ten-year old Pakistani Arfa Karim by a nine-year-old Indian girl (who could cite 1300 verses from the legendary poem of the Tamils, the Thirukkural already at the age of three); everyone then was overtaken by the Macedonian Marko Calasan who took his successful exam at the age of eight (then, before he reached 10, wrote a 300-page installation book for Windows 7). https://gizmodo.com/8-year-old-macedonian-boy-becomes-youngest-microsoft-ce-5134468

23 https://osztalyfonok.hu/cikk.php?id=1597

24 The only accepted and widely used interpretation is the concept innovation linked to Georgette Yakman's name. In 2015, a STEAM review was launched (https://scholarship.claremont.edu/steam/). Kimura's (2019) notion of "technoartescience" includes social science but construes integration rather in terms of the spiritual and not the community dimension.

25 Some earlier extension trials (like involving the "R" of Reading and wRiting as STREAM) wished to enrich the meaning of the notion "backwards", with the basic skills but this is clearly unreasonable, it is a blind alley. Integration is going on "sidewards", involving the omitted fields.

of tour", which is no sense to be illustrated with flagship projects because even the best practices so far show extreme diversity.)

The program of making scientific performance general at schools does not reflect to the crisis phenomena of public education and pedagogy but the epochal change of civilization.

At the end of the 19th century, the birth of the modern public education system and modern science was part of a comprehensive social macro-evolutionary transformation during which aristocratic control structures were replaced by bureaucratic control structures in almost each field of life, which started to serve the new system size and complexity effectively. Through several generations, school played a revolutionarily new role by successfully shifting the outlet towards higher qualification and positions of higher added value, being at the same time the engine of social mobility and the reduction in inequalities.

The mass of phenomena perceived as the "world crisis of education" from the 60's of the 20th century *did not reflect the inherent dysfunctions of the world of school and pedagogy but the process of the bureaucratic control structure becoming less and less appropriate* (Z. Karvalics, 2009, 2010). That is why all "pedagogical reforms" disregarding the fact that the school has to fulfil its system function in a changed social scope proved to be unsuccessful and ineffective. The core of this change is a new leap in system size and complexity that leads towards new patterns of work, society organization, resource consumption, distribution, autonomy, cooperation, coordination and responsibility. And although it seems that the clue is technology, artificial intelligence, the Big Data or the dynamics of the internet, in fact they are only components of the balancing mechanisms necessary for the new system level. I referred to this change when I suggested to complete the schoolbook theoretical triple (Politicum, Pedagogicum, Informatorium) with a fourth element, Civilisatorium (Z. Karvalics, 2013b). Today, I consider the raise in the value of human technology and economy as part of this and as a direction unthinkable without searching the ways leading to *substantial equality* formulated by István Mészáros. It depends on the school system and the pedagogical practice how much they can contribute to this already now, at the beginning of the transition. It is, however, sure that doing science and STESCHAM knowledge production push schools into this direction rather strongly.

The student performing science and producing knowledge is not any more simply the under-age subject of education but, owing to his/her contribution to and resource role in the solutions in the society understood as a life and problem community, is a partner to be emancipated

During the latest two or three decades, we have witnessed certain phenomena. Childhood, becoming an adult, selection of one's career path, founding a family and starting an independent life are delayed, taking place at a higher and higher age; meanwhile "digital natives" gain competences possible to be integrated into extra-school processes of problem solution at a lower and lower age. Recognizing and accepting this must (after the example of the Finnish teachers who were taught to use computers by children at the dawn of the online culture) necessarily change the attitudes of the school, the teacher, the parent and the society towards the children. This does not entail the radical revision of safeguard, taking care, development or education adapted to psychosocial specialities but the permanent re-arrangement of the learning and teaching environment the horizon of which leans, moving away from frontal forms, through embedding into game ecosystems being in line with the given age (Z. Karvalics, 2018) to, *amongst others*, involvement into knowledge producing mass communities. Belonging to various types of local, national and global communities can be experienced through research tasks and participative processes entailing knowledge production, as well, together with the evolution of the relevant structures of perception, identity and responsibility. In this transformation, involvement into the institutionalized systems of scientific performance and knowledge production is like a permanent initiation. Yes, like in former tribal societies where "abiding the test" was the way to get full admittance into the community.

This is why I think it has been high time for years to speak about *digital initiates* (Z. Karvalics, 2013d). By doing so we could not only renew the, sometimes really useless, "generation discourses" using the letter codes (X, Y, Z, Alpha) but could also inspire a set of "new alliances" between society and school, teacher and student, community and community.

Epilogue

As emphasized above, the vision of the theses is very normative. Of course, many current developments underpin their direction or "authenticity". The prime sense of considering them is that they are comparable to daily affairs, interventions, plans and innovative ideas. Do they point to this direction? Do they cross thresholds and contribute to the manifestation of the last mile?

Let us not be deceived by the fact that meanwhile bureaucratic control is fiercely defending all its beach-heads, even the ones it does not need. Politicum is striving to overcome Pedagogicum and Informatorium, neglecting Civilisatorium. And while at the domestic schools we can feel happy about thousands of tiny little steps as examples of successfully adapting to the changing world, the atavistic shades of the Past[26] appear many times to retard necessary and inevitable transformation not only in science pedagogy but the whole of public education.

Literature

- Barell, John (2003): *Developing More Curious Minds* Association for Supervision & Curriculum Development,
- Benedek, András (Szerk.) (2012): Digitális pedagógia 2.0. Typotex, Budapest,
- Christianakis, Mary (2010): Collaborative Research and Teacher Education *Issues in Teacher Education* (19) 2:109-125,
- Cooper, Beverley – Cowie, Bronwen (2010): Collaborative research for assessment for learning *Teaching and Teacher Education* (26) 4: 979-986.https://doi.org/10.1016/j.tate.2009.10.040,
- Csapó, Benő (2004): A tudásvagyon újratermelése Magyar Tudomány 11:1233-1239.
- Ginsburg, Kenneth R. (2011): *Building Resilience in Children and Teens: Giving Kids Roots and Wings* American Academy Of Pediatrics,
- Golfomitsou, **Stavroula et al. (2017):** The role of educators in promoting collaborative research», *CeROArt* http://journals.openedition.org/ceroart/5051 DOI: 10.4000/ceroart.5051,
- Hajnal, István (2008): Írásoktatás a középkori egyetemeken Gondolat, Budapest,
- Hecker, Susanne et al. (Eds) (2019): *Citizen Science: Innovation in Open Science, Society and Policy* UCL Press,
- Horváth, Cz. János (2012): A mikrotartalmak: avagy egy lépéssel tovább a 2.0-ás úton In: Benedek, 2012: 195-220.,

[26] Most of what we can say about the counterproductive nature of the centralization efforts in education management appears in public thinking and partly in the professional literature, as well. But much less words are spoken, for example, about the new segregation wave that has started in the rural society as a consequence of consciously directed desecularization, the forceful "churchification" of schools. What would the legendary teacher persons of the fantastic church schools, who were the pioneers of creating up-to-date scientific literacy in the "suffered" institutions of the socialist era, say about this? Those who already then, without being aware of it, put the world of STESCHAM and generations of "predigital initiated" on their way?

- Ibata, Neil G. et al. (2014): Velocity anti-correlation of diametrically opposed galaxy satellites in the low-redshift Universe Nature 511:7511. DOI: 10.1038/nature13481,
- Jhangiani. Rajiv S. – Biswas-Diener, Robert (Eds) (2017): Open: The Philosophy and Practices that are Revolutionizing Education and Science Ubiquity Press,
- Kimura, Yasuhiko Genku (2019): Technology, Art & Science of Homo Deus BFF keynote, April http://www.bfutureforum.com/wp-content/uploads/2019/04/TECHNOLOGY-ART-SCIENCE-OF-HOMO-DEUS.pdf,
- Logan, Robert K (1986): *The Alphabet Effect* William Morrow and Company Inc, New York,
- Malita, Mircea (1976): *Eszmék faggatása* Albatrosz Könyvkiadó, Bukarest,
- Nagy, Lászlóné (2010) *A kutatásalapú tanulás/tanítás ('inquiry-based learning/teaching', IBL) és a természettudományok tanítása. Iskolakultúra* (20) 12: 31-51.,
- Pascal, Charles E. (2009): *With Our Best Future in Mind Implementing Early Learning in Ontario Report to the Premier by the Special Advisor on Early Learning* Queen's Printer for Ontario https://www.oise.utoronto.ca/atkinson/UserFiles/File/Resources_Topics/With_Our_Best_Future_In_Mind_-_Charles_Pascal.pdf,
- Ripley, Amanda (2014): *The Smartest Kids in the World: And How They Got That Way* Simon & Schuster,
- Rocard, Michel (Chair) (2007): Science Education Now: A Renewed Pedagogy for the Future of Europe Directorate-General for Research, Science, Economy and Society, Brussels https://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf,
- Roberts, Mike (1994): Skills for Self Managed Learning: Autonomous Learning by Research Projects, Education Now Publishing Co-operative,
- Schallies, Michael – Lembens, Anja (2002): Student Learning by Research *Journal of Biological Education* (37) 1: 13-17,
- Tesoriero, Heather Won (2018): The Class. A Life-Changing Teacher, His World-Changing Kids, and the Most Inventive Classroom in America Penguin Random House,
- Tough, Paul (2012): *How Children Succeed: Grit, Curiosity, and the Hidden Power of Character* Houghton Mifflin Harcourt,
- Tóth, Albert Dr. (2004): Kitüntetett nomádok *TermészetBúvár* 6:38-39.
- Wells, Gordon (2001): The development of a community of inquirers. In: Wells, Gordon (Ed.): Action, talk, & text: Learning and teaching through inquiry New York: Teachers College Press 1-22.,
- Z. Karvalics László (2007): A cyber-infrastruktúra mint aktuális kihívás és mint tudományszociológiai probléma *Magyar Tudomány* 4: 475-489.,
- Z. Karvalics László (2008a): Az adatsilóktól a tudomány kontrollforradalmáig *Magyar Tudomány* 3: 352-363.,
- Z. Karvalics, László (2008b): Humántudományok Mérnökföldön (Bölcsészország elműszakiasítása), Élet és Irodalom február 8: 12-13.,
- Z. Karvalics László (2009): Két kontrollforradalom között: az információs társadalom közoktatásának körvonalai I. Oktatás- Informatika 2: 2-16.,
- Z. Karvalics László (2010): Két kontrollforradalom között: az információs társadalom közoktatásának körvonalai II. Oktatás- Informatika 2010/1-2: 2-13.,
- Z. Karvalics László (2013a): Tudományos ismeretterjesztés, tudomány és digitális kultúra, *Könyv és Nevelés* 3: 80-85.,
- Z. Karvalics László (2013b): „Jelentés-teli világra nyíló szárnyas kapu". Egy logokratikus médiapedagógia körvonalai In: Médiatudatosság az oktatásban. Konferenciakötet. Szerk. Pálfi Erika OFI, Budapest, 53-59.o.,
- Z. Karvalics László (2013c): From Scientific Literacy to Lifelong Research: A Social Innovation Approach In: Kurbanoğlu, Serap et al. (Eds.): Worldwide Commonalities and Challenges in

Information Literacy Research and Practice European Conference on Information Literacy, ECIL 2013 Istanbul, Turkey, October 22-25, 2013 Revised Selected Papers Springer 126-133.,

- Z. Karvalics László (2013d): „Digitális beavatottak” egy hiperkonnektív világban In: Szekszárdi Júlia (szerk.): Digitális (de)generáció 2.0. Underground Kiadó, Budapest, 62-78.,
- Z. Karvalics László (2015): Kutatni szabad *Szitakötő* 31. 3:36-37.,
- Z. Karvalics László (2018): Noogames: játékkultúra és civilizációs horizont *Információs Társadalom* 1:49-65.,
- Z. Karvalics László (2019a): Állampolgári tudomány és önkéntes erőforrásszerzés mint paradigmatikus, szakpolitikai és menedzsment-kihívás *Új Magyar Közigazgatás* 1: 44-53.,
- Z. Karvalics László (2019b): A tudományművelés és a tudományokban való jártasság, mint emberi jog. Egy arkhimédészi pont azonosítása *Acta Humana* 3: 119-135.,
- Z. Karvalics László (2019c): Hogyan kapcsolódhat össze a humán technológia térfoglalása a digitális kultúra és az oktatás jövőjével? In: Hülber, László et al. (szerk.): Oktatás-informatika-pedagógia konferencia 2019 Kapitális Kft., Debrecen 19-21.